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CUMULATIVE EFFECTS OF HEAT STRESS ON MILK PRODUCTION IN HOLSTEIN HERDS

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SUMMARY:

The applicability of existing heat stress predictive models were tested using field data. Genetic and management differences in herds were minimized by normalizing daily individual herd production to its own annual average production. Only Holstein herds housed in uninsulated free stall housing systems were used. Ambient temperature and Temperature Humidity Index (THI) averaged over varying time intervals were used to predict changes in milk production. The cumulative nature of the exposure/response heat stress relationship is illustrated.

KEYWORDS:

Heat Stress, Milk Production, Prediction

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CUMULATIVE EFFECTS OF HEAT STRESS ON MILK PRODUCTION IN HOLSTEIN HERDS

INTRODUCTION

The effect of heat stress on milk production must be known to make rational decisions regarding the economics of installing environmental control systems in dairy housing. The interest of the environmental control engineer is to predict the climatic conditions at which heat stress begins to reduce milk production and the magnitude of this effect on whole herd performance. Studies relating air temperature and other climatic variables to milk production have been presented previously in the literature (Berry et al, 1964; McDowell et al, 1976; NRC, 1981; Linvill and Pardue, 1985). These studies are of two main types; 1) laboratory studies in which production data from individual animals is correlated with controlled climatic variables, and 2) field studies in which production data, usually from a single herd, is correlated with naturally occurring variations in climatic conditions. The correlation between climatic variables and daily milk yields in these studies ranges from 0.6 for laboratory studies to 0.3 or less for field studies of individual herds. This indicates the difficulty in adequately describing the impact of heat stress on milk production.

The most extensive laboratory studies have been done in the Missouri psychroenergetic laboratory using small groups of cows in controlled climatic chambers (Berry et al, 1964; Yeck and Stewart, 1959). The tests were performed by acclimating groups of 12 cows to a specific temperature/humidity condition for 1 to 2 weeks and then measuring the resulting milk production. The temperature range of these studies was -12 to 35 C. A model developed from this data, (Berry et al, 1964), predicted the milk production thermo-neutral zone (the range of temperatures over which milk production is not significantly affected) to be from -12 to 24 c for Holstein cows. The correlation coefficient (R^2) between temperature and humidity and decline in milk production was .56 over the temperature range of 24 to 35 C.

It is questionable whether acclimated response data can be applied to natural climatic conditions, which are constantly changing. An examination of a representative response graph for one cow from the Missouri data shows that milk production fell for a period of three to five days before reaching a steady level for a given set of test conditions. Experiments in the Missouri trials were also done to examine the effects of diurnal variation in temperature. A given diurnal fluctuation was imposed for 1 to 2 weeks. The results of these studies showed that animal response matched closely that of the average temperature of the diurnal cycle after several days of exposure. It has also been shown that cows which were allowed to recover from heat stress during the night showed no significant decline in milk production even though heat stress was experienced during the day (NRC, 1981).

Extensive field studies were performed by McDowell et al, 1976 and reported in NRC, 1981. Production records were kept for a Holstein herd of about 280 animals over a 12 year period. The animals consumed a diet of alfalfa hay, corn silage, and concentrates at a ratio of approximately 60 percent roughage and 40 percent concentrates. Expected milk yield corrected to 3.7 percent fat was predicted to be constant over the temperature range -5 C to +20 C. In the temperature range 20 to 30 C milk production was predicted to fall linearly at 1.5 percent per degree C. Daily climatic variables were found to account for 3 to 27 percent of the variation in milk production with the greatest influence in the first 60 days of lactation.

The McDowell prediction, developed from field data, differs from that of Berry, developed from acclimated laboratory data, in two respects. First, the decline in milk yield is predicted by McDowell to begin at 20 C rather than 24 C as predicted by Berry. Second, the decline is less dramatic in the McDowell prediction at 1.5 percent per degree as compared to 5 percent per degree in the temperature range 24 to 30 C. It should be noted however that the correlation coefficients in both data sets are low and both prediction equations fall within the scatter of the data. The low correlations between climatic factors and milk production even under very controlled conditions indicates that there is a great deal of variation between animals due to inherent genetic differences as reported by McDowell et al, 1976. The slope and intercept of the milk production verses temperature predictive equation can depend on subjective assumptions made about the extent of the thermo-neutral zone when such a large degree of scatter is present in the data.

In another field study of a single herd, Linvill and Pardue (1985) found that the best predictor of the effects of heat stress used the hours the THI exceeded 74 in the preceding 4 days and the hours the THI exceeded 80 on the previous day. These results and an examination of the Missouri data indicate that animals respond to climatic conditions averaged over time rather than to immediate conditions, provided physiological damage thresholds are not reached. Similar observations have been made for laying birds (Timmons and Gates, 1988). Acclimated response and daily average temperature is, however, still commonly used as a predictive equation for the effects of heat stress on milk production.

The objective of this study is to compare the suitability of predictive equations derived from laboratory and field experiments for predicting the effects of temperature on the average milk production from many herds under field conditions and to determine an appropriate averaging interval for climatic conditions.

MATERIALS AND METHODS

Milk production data was obtained from the records of the New York State Dairy Herd Improvement Program (DHI). Weather data for Ithaca New York was obtained from the Cornell University Meteorology department for the corresponding time period. The effect of temperature was isolated to the greatest degree possible. Data from 245 herds within a 50 mile radius of Ithaca were used to minimize differences in air temperature among data sets. Only Holstein herds housed in uninsulated free stall barns were considered to eliminate difference due to breed and housing system. The average daily temperature in this type of housing very near to the average outside temperature during the summer when sidewalls are opened promoting high air exchange rates.

Differences in milk production due to genetic makeup of the herd and breeding and other management practices of the individual herdsman were minimized by normalizing the production data for each herd in the following manner. The production record for each herd consisted of 12 sample days approximately one month apart. The total weight of milk produced on the sample day was corrected to a constant 3.7 percent milk fat and divided by the number of cows being milked on that day. These 12 samples were then averaged to yield the annual average fat corrected milk production per cow for each herd. The 12 daily herd averages were then divided the annual herd average for each herd. The fat corrected milk production per cow for each herd is thus normalized against its own yearly average.

The normalized fat corrected milk production data was regresses against the average temperature and Temperature Humidity Index (THI) on the sample day and averaged over periods ranging from 1 to 15 days prior to the sample day. The daily low temperature was used as the dew point to determine relative humidity, corresponding to the method used by Linvill and Pardue (1985). Regression analysis was also performed to determine the upper limit of the thermo-neutral zone. The daily normalized milk production data were regressed against average temperature and THI while restricting the data sets to days in which the average temperature was above a specified level. The cutoff levels ranged from 20 to 24 C corresponding to the range predicted in the literature.

It was expected that the slope of the regression line decrease and the intercept and the correlation coefficient increase as the cutoff level of the temperature increases within the thermo-neutral zone. After the upper limit of the thermo-neutral zone is reached the slope, intercept and correlation should stay relatively constant as the cutoff temperature is increased further. Regression analysis was also performed on normalized fat corrected milk verses the average days in milk (DIM) of the herd and the herd size on the sample day.

RESULTS AND DISCUSSION

The correlation between daily average temperature and normalized milk production was less than 1 percent and not statistically significant. Correlation increased as the averaging interval increased. Daily and time averaged THI produced equal or lower correlations than temperature when used as a prediction variable. The highest correlation coefficient was obtained using the ten day average temperature as the sole climatic variable and 20 C as the upper limit of the thermo-neutral zone:

$$FCM = 129 - 1.5\ T_{10}$$
$$(20 < T_{10} < 25;\ R^2 = .20)$$

where: FCM = Percent of annual average fat corrected milk production per cow per day

T_{10} = 10 day average temperature

This result suggests illustrates the cumulative nature of the response of the herd to temperature. Cows can apparently use stored energy or increase their cooling mechanisms to cope with heat stress of short duration. This is an extremely important point. Most of the currently used prediction models suggest prediction of milk production loss using daily average temperatures and humidities. This study shows that a longer term average of climatic conditions will result in better prediction accuracy.

The results of the thermo-neutral regression analysis confirmed the 20 °C level as the upper limit of the thermo-neutral zone. The slope of the regression line decreases and the intercept and the correlation coefficient increase until the 20 °C cutoff level.

The highest daily average temperature was 32°C, and the highest ten day average temperature was 25°C in the data set used. This did not allow for verification of response to heat stress at temperatures significantly outside the thermo-neutral zone. These temperature extremes are typical of northern states indicating that severe heat stress is not commonly encountered in these regions. A study using probabilities of occurrence of daily climatic parameters indicated expected losses in production of less than .3 percent per year due to heat stress in New York State (Hahn and Osburn, 1970). The use of daily averages rather than longer term averages probably resulted in an over-estimated effect of temperature on lost milk production.

The average days in milk of the herd was found to have a significant correlation with the herd average fat corrected milk production when the entire years data set was used:

$$FCM = 116 - .11\ DIM$$
$$(R^2 = .22)$$

where: DIM = Average days in milk of milking herd

The herd size had no significant effect on the normalized fat corrected milk production. Using both the ten day average temperature and herd average days in milk as prediction variables resulted in the following equation:

$$FCM = 146 - .10\ DIM - 1.5\ T_{10}$$
$$(20<T_{10}<25,\ \ 100 <DIM<260,\ \ R^2 = .32\ )$$

The correlation coefficient using these two predictors is as high as those attained in previous field studies using up to 12 predictors.

CONCLUSIONS

The heat stress/milk production relationship based on herd average fat corrected milk production for 245 Holstein dairy herds over the temperature range of 20 to 25 C was found to correspond closely to that presented by McDowell et al, 1976 and reported in NRC, 1981. The effect of heat stress on herd average fat corrected milk production was predicted within the accuracy of previous field and laboratory studies using ten day average temperature as the sole climatic variable. It is important to use temperatures averaged over several days as opposed to the current practice of daily averages to predict temperature effects on milk production. The herd average days in milk was also found to have a significant effect on milk production. Much of the variation in milk production appears to be due to genetic difference between animals and other environmental and management factors. The occurrence of heat stress reducing milk production by more than 10 percent per day or 1 percent per year in northern states is extremely rare.

REFERENCES

Berry, I.L., M.D. Shanklin, and H.D. Johnson. 1964. Dairy shelter design based on milk production decline as affected by temperature and humidity. Trans. ASAE. 45:329.

Hahn, G.L and D.D. Osburn. 1970. Feasibility of evaporative cooling for dairy cattle based on expected production losses. Trans. ASAE. 51:289.

Linvill, D.E., and F.E. Pardue. 1985. Summertime dairy production in South Carolina. ASAE technical paper No. 85-4025.

McDowell, R.E., N.W. Hooven, and J.K. Camoens. 1976. Effects of climate on performance of holsteins in fist lactation, J. Dairy Science. 59:965-973.

National Research Council, 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. Subcommittee on Environmental Stress, Committee on Animal Nutrition, Board on Agricultural and Renewable Resources, Commission on Natural Resources, National Academy Press, Washington, D.C., 152 pp.

Timmons, M.B. and R.S. Gates. 1988. Energetic model of production characteristics for tom turkeys. ASAE Trans 31(5):1544.

Yeck. R.G., and R.E. Stewart. 1959. A ten-year summary of the psychroenergetic laboratory dairy cattle research at the University of Missouri. Trans. ASAE 40:71-77.