Northern New York Agricultural Development Program
2017 Project Report

The Impact of Episodic Heat Stress on Lying Behavior and Lameness of Lactating Dairy Cows on NNY Farms

Project Leaders:

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Background:

Dairy cattle respond to heat stress in several ways including greater standing time, reduced eating activity, greater water consumption, less rumination, lower dry matter intake, and reduced milk production and reproductive performance (West, 2003; Tapki and Sahin, 2006).

Although numerous studies have been conducted that evaluate cow response to heat stress, few studies have been conducted in the northeastern United States where episodic bouts of heat stress are typical. Anecdotally, dairy farmers in this region often state that bouts of heat stress that occur early in the summer (June), or late in the summer (September), have the most dramatic negative effects.

Heat stress is evaluated by calculating the temperature-humidity index (THI). The following equation uses ambient temperature (Tdb) and relative humidity (RH) to determine THI in lactating dairy cows: $(1.8 * Tdb + 32) – [(.55 - .0055 * RH) * (1.8 * Tdb – 26)]$ (NRC, 1971).

The economic consequences of heat stress on dairy herds has been documented and discussed by several researchers (DeVries, 2012; St. Pierre, 2003). In the United States, heat stress in dairy cattle can cause the industry a loss of $1.5 billion a year (St. Pierre, 2003). DeVries (2012) presented data showing that the economic loss for heat-stressed cows with minimal abatement ranged from greater than $600/cow/yr for Florida and Texas to $72/cow per year for Wisconsin.

The annual hours of heat stress for Florida and Texas, as assessed by a THI > 70, were 49 and 36%, respectively, whereas Wisconsin was only 9%. There are dramatic differences by region of the US in severity of heat stress, but St-Pierre (2001) still estimated a greater than 2:1 return on investment for heat stress abatement in New York.

The short- and longer-term consequences of heat stress on health issues, such as lameness, are perhaps under-appreciated, especially related to the more moderate heat stress typical of northern states. Cook et al. (2007) observed the behavioral and lameness changes that occurred between early June and September as THI ranged from 56.2 to 73.8. Even with these mild to moderate heat stress conditions, lying time decreased from 10.9 to 7.9 hours per day (h/d) from the coolest to the hottest conditions while standing in the alley increased from 2.6 to 4.5 h/d. This 3-hour decrease in lying time was associated with greater claw horn lesions and overall herd lameness.

Severe consequences of heat stress require the need for heat abatement strategies to be implemented. In 2016, Miner Institute conducted a study funded by the Northern New York Agricultural Development Program (NNYADP) that evaluated three different pens of cows with different cooling strategies at Miner Institute. A minimal heat abatement pen using only fans over freestall beds was compared to a moderate heat abatement pen with fans over feed alley and sand-bedded freestalls and a maximum heat abatement pen with fans equipped with a mister system over alley and freestalls.

The findings of this study illustrated that lying time was depressed for all heat abatement systems above a THI of 72, but the extent of reduction in lying time was lessened with more aggressive heat abatement systems. For moderate and maximal heat abatement systems, the stall standing index did not change with increasing THI, indicating that cows subjected to moderate or maximal heat abatement systems do not need to stand in the stalls to cool themselves. A limitation of this study was that all cows were exposed to a soaker system in the holding area of the milking parlor three times per day during heat events.

Objectives:

The objective of this study in 2017 was to assess the impact of episodic heat stress within varying farm management systems with different degrees of heat abatement on lameness, behavioral, and productive responses of dairy cattle from June through September in Northern New York State.

Methods:

Research was conducted on four farms in Clinton and Franklin counties with varying housing conditions and heat abatement systems. On each farm, early to mid-lactation Holstein or Jersey cows (n=30) were identified at the beginning of the study based upon the expectation that they would remain in the same lactating group for the duration of the study and were not lame (lameness score ≤ 2). This group of cows served as a focal group for each farm (Table 1).

The four farms had the following designs and heat abatement systems:

Farm A: Free stall pen with 77 sand-bedded stalls that housed 80 cows, stocked consistently at 104%, oriented east-west in a six-row barn, with natural ventilation only.

The pen had 105 feet of neck rail with three headlocks at the west end of the pen, and one large waterer at either end of the middle stall rows. Cows were milked twice daily at 0400h and 1500h in a double-ten herringbone parlor and normally fed once daily. However, on hot days their feed was split between two feed-outs.

The holding area had four fans on the east side wall with a diameter of 26 inches and three fans at the front facing into the holding area with a diameter of 34 inches. A sprinkler system was utilized in the holding area when the ambient temperature was at or above 75˚F and water pressure was high enough.

Farm B: Free stall pen with 103 functional sand-bedded stalls that housed 144-146 cows, stocked at 139-142%, oriented north-south in a six-row barn, and utilizing five box fans with a diameter of 52 inches above the stalls closest to the feed bunk and five box fans with a diameter of 44 inches above the middle row of stalls within the pen.

The pen had 86 headlocks and three large waterers, one at either end and one in the middle of the pen. Cows were fed once daily and milked twice daily at 0700h and 1700h in a double-twelve parallel parlor.

The holding area had three fans on the west side wall with a diameter of 36 inches. There was one fan on both sides of the front of the parlor that, when turned on, would push air across the backs of the cows in the parlor and into the holding area.

Farm C: Two-row tie-stall barn with rubber mats bedded with shavings and one cow tied per stall, oriented north-south, and utilizing naturally-assisted ventilation with two fans at the north end of the barn with a diameter of 36 inches pulling air through the barn. There was one fan with a diameter of 21 inches above both feed alleys about half way down the length of the tie-stall rows. There was one fan with a diameter of 48 inches on the south facing wall beyond the tie-stall rows and one fan with a diameter of 48 inches on a north facing short wall that was east of the tie-stall rows. A portable box fan with a diameter of 36 inches was placed at the south end entryway of the barn on hot days and was turned on at the discretion of the farmer.

Cows were fed and milked twice daily at 0530h and 1630h in their stalls.

Farm D: Free stall pen in a six-row barn and converted two-row tie-stall barn with 133 functional mattresses and shavings bedded stalls that housed 135-140 cows, stocked at 102-105%, oriented north-south, and utilizing fans over the stalls in addition to forced ventilation fans. There were three forced-ventilation fans on the north end outside wall with a diameter of 60 inches, three fans with a diameter of 22 inches above both rows in the converted tie stall barn, and three fans with a diameter of 52 inches above both middle stall rows in the free-stall barn. Cows were allowed continuous, at-will access to both areas.

The pen had 106 headlocks, two large waterers at the north end of the free-stall area, two small waterers in the middle of the free-stall area, and two small waterers at the south end of the free-stall area.

Cows were fed once daily and milked twice daily at 0800h and 2000h in a double-ten herringbone parlor. There were three fans with a diameter of 36 inches at the front facing into the holding area, and one fan with a diameter of 24 inches above both sides of the parlor.

Measurements

Environmental conditions. Temperature and relative humidity were recorded in ten-minute intervals using a Kestrel® DROP D2AG data logger (Nielsen-Kellerman Company, Boothwyn, PA) from the beginning of July 2017 through the end of September 2017 (Fig.1). Each device was located centrally within the pen and mounted at cow height, inside a PVC pipe with holes drilled to allow airflow to most accurately capture the cow environment. THI was calculated by the Kestrel device using the following NRC (1971) THI equation: $(1.8 * Tdb + 32) – [(.55 - .0055 * RH) * (1.8 * Tdb – 26)]$.

Lameness. All cows were scored at the beginning and end of the study for locomotion on a flat and level surface. Cows housed in a free stall pen were scored using a 5-point scoring system where 1 = normal, 2 = mildly lame, 3 = moderately lame, 4 = lame, and 5= severely lame (Sprecher, 1997). A cow was excluded from the focal group if she scored above a 2 in the 5-point scoring system.

Cows housed and milked in the tie-stall were scored using the stall lameness score system where NL = not lame and L = lame (Leach et al., 2009). Due to the limited number of cows available, no cows housed in the tie-stall were excluded if characterized as lame using the stall lameness score system.

Behavioral assessment. Lying and standing behavior, i.e., time spent lying and standing, bouts, and distribution of bouts during 24 h, were measured continuously using leg-mounted HOBO Pendant G data loggers (Onset Computer Corporation, Bourne, MA) that were changed out on a weekly basis. These loggers measured and recorded the y-tilt of the cow's leg every minute to distinguish between standing and lying behavior. A "bout" was characterized by three consecutive minutes of the same behavior.

Four days of cool weather (mean THI <65, COOL) and four days of hot weather (mean THI > 70, HOT) were selected over the course of the summer. Lying behavior summarized for COOL days was considered optimal resting time for the farm, while lying behavior summarized from HOT days was considered the result of heat stress for the farm.

Indices of cow comfort were assessed using a field camera (Panoramic 150i, Moultrie LLC, Birmingham, AL) mounted in the pen to overlook stalls. Images of stall use were taken every 15 minutes over the course of the day and stall use and stall standing measures were assessed two hours before and after milking on a daily basis. The stall standing index (SSI) was calculated by dividing the number of cows standing in stalls by the total number of cows in contact with a stall. The relationships between these assessments of behavior and relative THI were evaluated for each herd over the course of the study.

Lactation performance. Bulk tank yield and milk composition were monitored throughout the study period. Milk payment records were accessed and used to assess milk composition (fat, true protein, urea nitrogen, somatic cell count, and fatty acid profiles) of bulk tanks on three of the four farms. On the fourth farm, daily bulk tank samples were analyzed for milk composition by the Miner Institute Milk Laboratory.

Statistical analysis.

All data were analyzed within-farm; no across-farms' comparisons were made among Farms A-D.

Differences in lameness: not lame vs. lame from beginning to the end of the study period within farms were analyzed using Proc Freq and significance was determined Chi-square.

Lying behavior was summarized and analyzed by farm using Proc Mixed procedure of Statistical Analysis Software (SAS) to evaluate differences in daily lying time (h/d) and frequency of lying bouts (n/d) for COOL and HOT days. Significance was declared at a probability of $P < 0.05$ and tendency at $0.10 \geq P > 0.05$.

The predictive power of temperature and humidity on bulk tank milk yield and milk composition was assessed by farm using R statistical software. Each environmental variable was represented in the model as eight means, one for each six-hour time block in a 48-hour period. This 48-hour period consisted of the day on which the milk properties were measured and the preceding day.

Results and Discussion:

Throughout the duration of the study, there were many periods of mild temperatures when the average THI was less than 68, broken up by a few days when the average THI was greater than or equal to 68 (Fig. 1). This allowed for the evaluation of the impact of episodic heat stress events on the lying behavior, lameness, and production performance of dairy cows on four different dairy farms with varying management and heat abatement systems (Table 1).

Episodic Heat Stress and Lameness. Of the focal animals that were lameness scored (Fig. 2), the percentage of cows not lame at the start and at the end of the study were similar for both Farms B and C. The percentage of cows lame at the end of the study increased for both farms A and D.

Episodic Heat Stress and Lying Time.
Farm A
Figure 3 illustrates the change in lying time relative to the minutes per day that THI was ≥ 68 for the focal animals on Farm A. As the minutes per day that THI was ≥ 68 increased, the amount of time spent lying decreased. From cool to hot days, the lying time decreased 2.5 hours from 12.8 hours to 10.3 hours per day, and lying bouts per day increased from 8.9 to 9.5 (Table 2).

Farm B
Figure 4 shows the change in lying time relative to the minutes per day that THI was ≥ 68 for the focal animals on Farm B. Similar to Farm A, lying time decreased in response to increased minutes/d that THI ≥ 68. Lying time decreased from 11.5 hours to 10.3 per day, a 1.5-hour difference (Table 2). However, there was no difference observed in lying bouts.

Farm C
The change in lying time relative to the minutes per day that THI was ≥ 68 shows similar sensitivities of the focal animals on Farm C to heat stress (Fig. 5). As the minutes per day that THI was ≥ 68 increased, lying time decreased. From cool to hot days, the amount of time spent lying decreased from 12.8 hours to 11.1 hours per day, a 1.7-hour difference (Table 2). However, no differences in lying bouts were observed.

Farm D
The change in lying time relative to minutes per day that THI was ≥ 68 on Farm D is illustrated in Figure 6. Lying time decreased as minutes per day that THI was ≥ 68 increased. From cool to hot days, lying time decreased 1.7 hours, from 10.3 hours to 8.6 hours per day (Table 2). There was no difference observed in lying bouts.

Episodic Heat Stress and Milk Production. Thirty-two percent of the variability in milk protein for Farm A could be explained by temperature and humidity while 0%, 0%, and 9% of variability in milk protein were able to be explained by the same environmental measures on Farms B, C and D, respectively (Table 3). As THI increased, milk protein decreased for Farm A that had no free-stall heat stress abatement system in place. Other bulk tank measurements showing a moderate relationship with temperature and humidity were preformed fatty acids for Farm A ($R^2 = 0.19$) and bulk tank milk yield ($R^2 = 0.11$) for Farm B.

Conclusions/Outcomes/Impacts:

- It is clear that dairy cows in Northern New York are adversely impacted by episodic bouts of heat stress with all farms being impacted to varying degrees regardless of type of heat abatement system employed.

- Cows on farms with minimal heat abatement are more susceptible to heat stress with decreased resting time, increased lameness, and decreased milk protein content, which results in a negative impact on farm profitability.

Outreach:

Results from this study will be presented at the national meeting of the American Dairy Science Association in Knoxville, TN, in June 2018 and at Dairy Day at Miner Institute in December 2018. In addition, a Miner Institute Farm Report article will be written in 2018 summarizing our findings.

Next Steps:

Summarization of stall standing index data will be completed and presented in future presentations and publications of this study. A second year of this study will be conducted in 2018 evaluating similar and additional parameters such as bunching behavior.

Acknowledgments:

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For More Information:

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APPENDIX: Tables and Figures, NNY Dairy Cow Heat Stress Study, 2017.

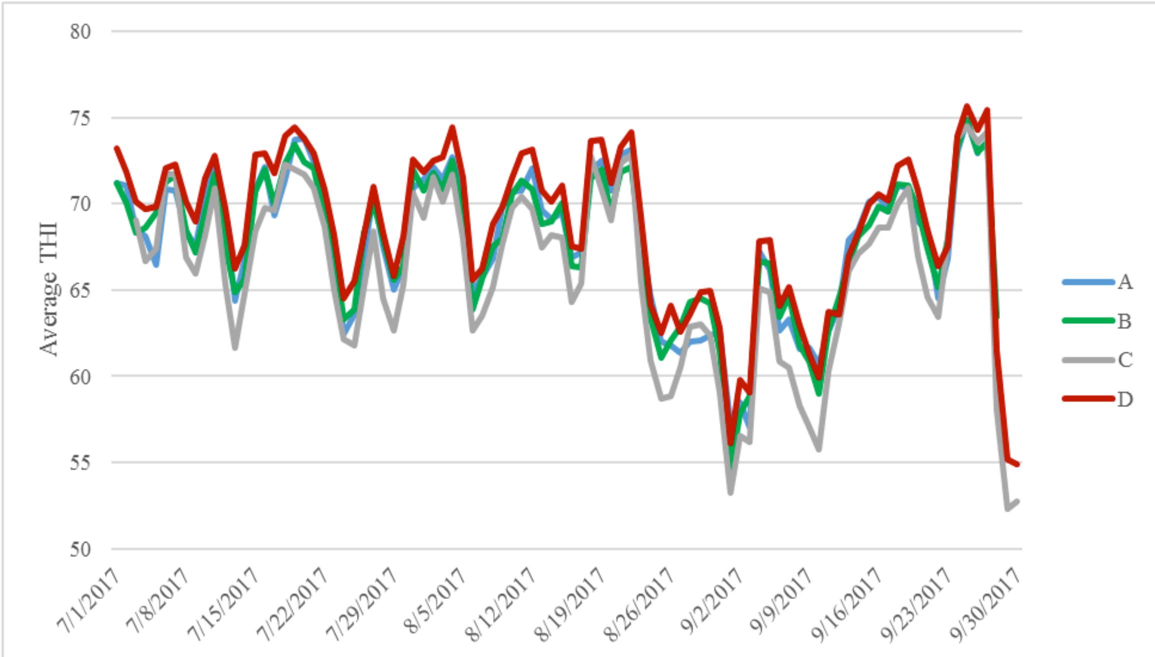

Figure 0. Average temperature humidity index (THI) by farm from July 1 through September 30, 2017; NNY Dairy Cow Heat Stress Study, 2017.

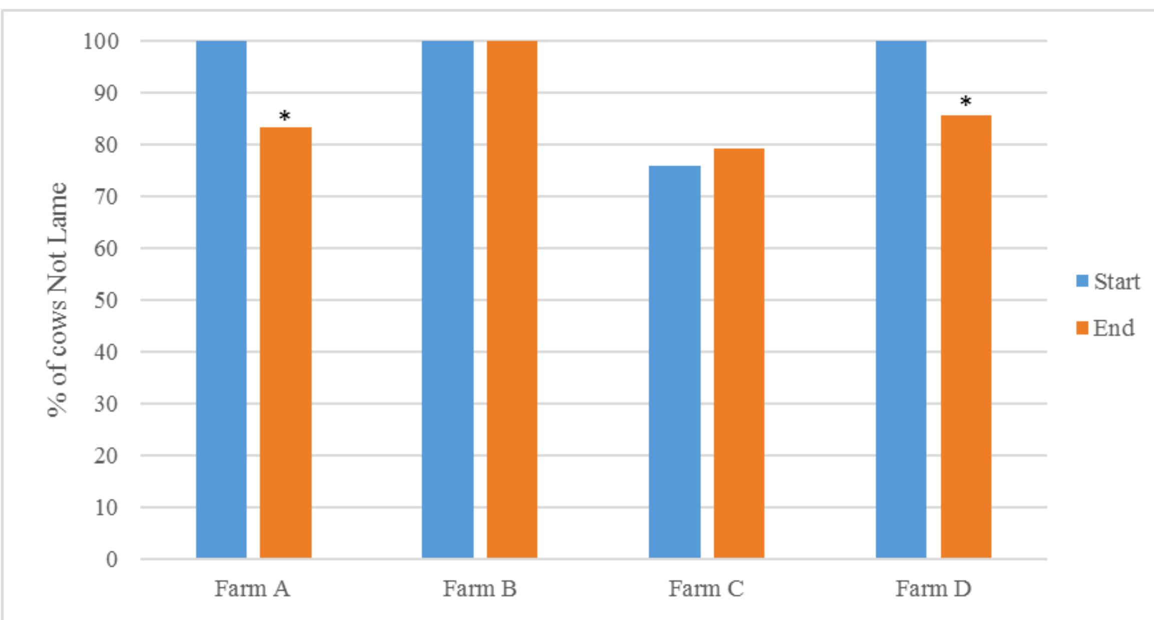

Figure 2. Percentage of focal animals that were not lame at the start and end of the study. Significant difference (*P*<0.05) in percent of cows not lame within farm from start to end of the study denoted by asterisk (*). NNY Dairy Cow Heat Stress Study, 2017.

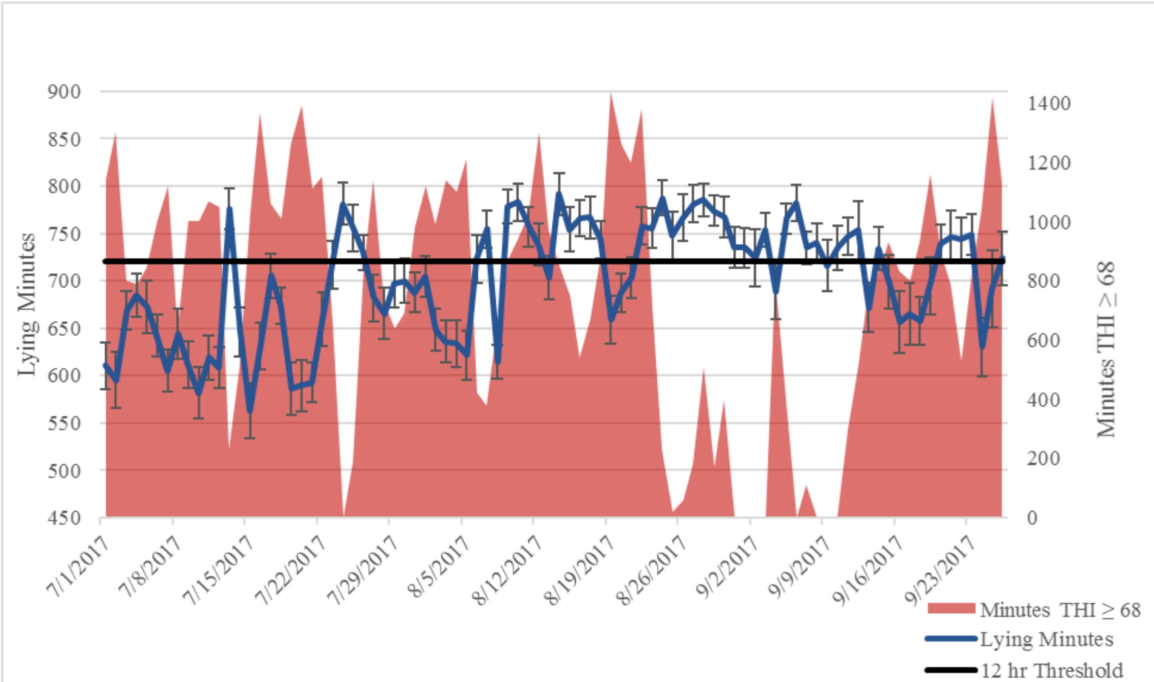

Figure 3. Lying time (minutes/d) relative to minutes THI ≥ 68 for Farm A. ***NNY Dairy Cow Heat Stress Study, 2017.***

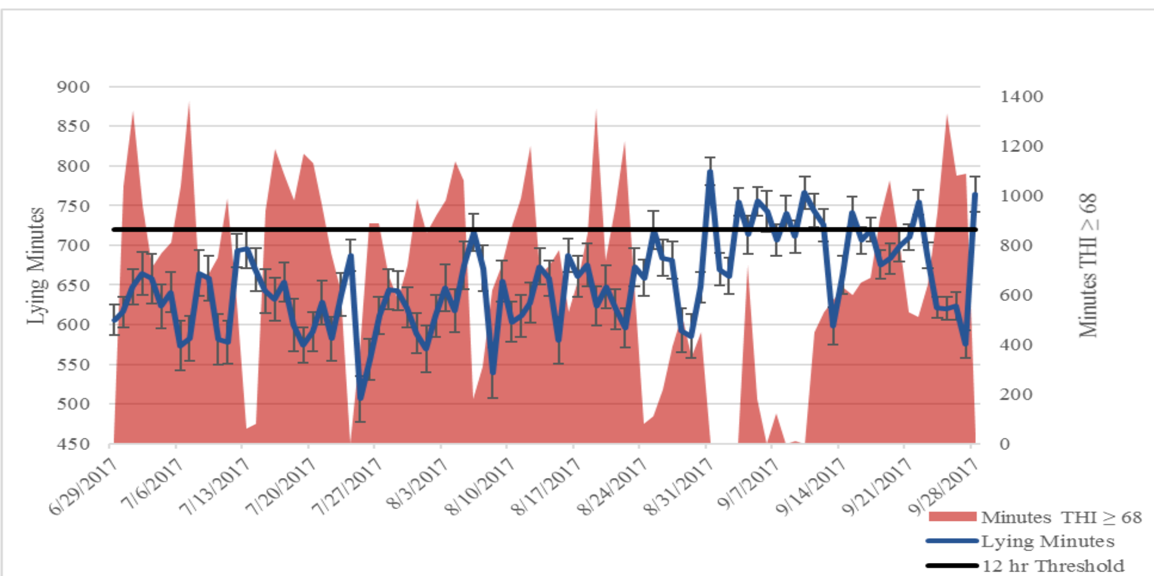

Figure 4. Lying time (minutes/d) relative to minutes THI ≥ 68 for Farm B. NNY Dairy Cow Heat Stress Study, 2017.

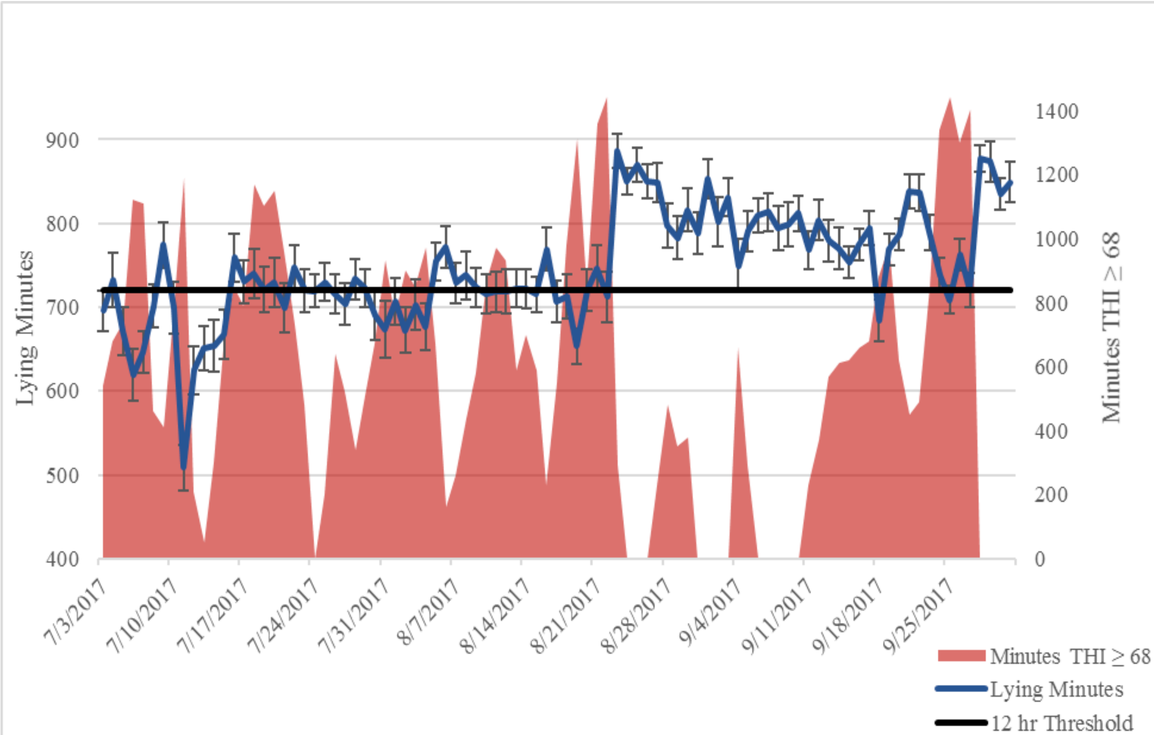

Figure 5. Lying time (minutes/d) relative to minutes THI ≥ 68 for Farm C. NNY Dairy Cow Heat Stress Study, 2017.

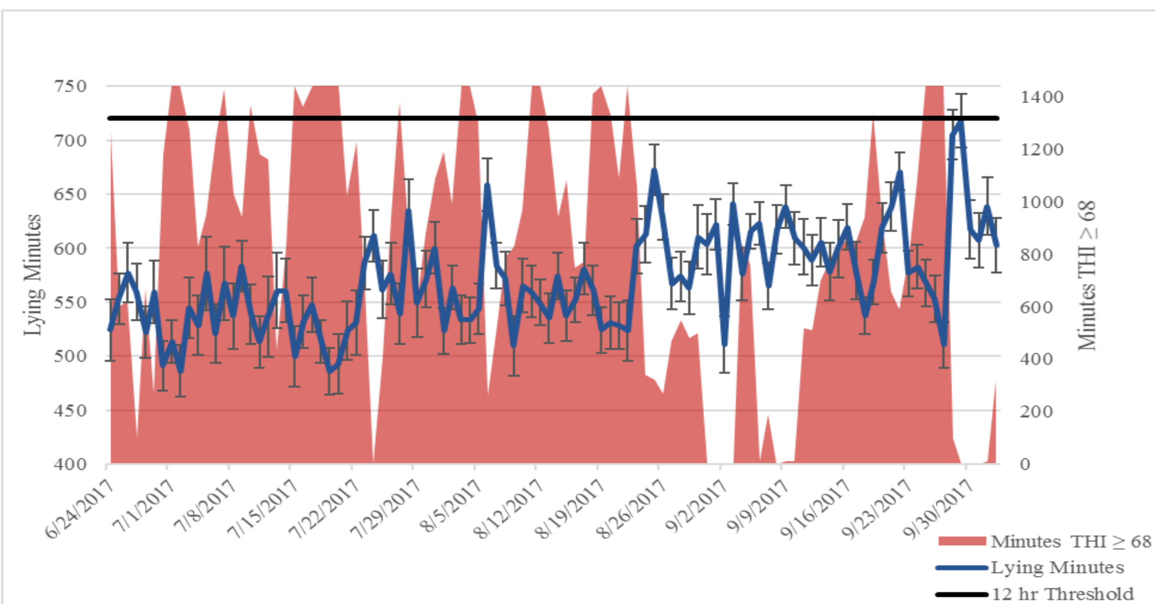

Figure 6. Lying time (minutes/d) relative to minutes THI ≥ 68 for Farm D. NNY Dairy Cow Heat Stress Study, 2017.

Table 1. Herd descriptions of four farms with average days in milk and milk production of focal animals at start of study on each farm, NNY Dairy Cow Heat Stress Study, 2017.

	Herd Description			Focal Animal Description	
	Herd Size	**Breed**	**Pen Setup**	**DIM (±SD)**	**Milk Production (lbs±SD)**
Farm A	287	Holstein	Free Stall	112 ± 28	113 ± 19
Farm B	650	Holstein	Free Stall	87 ± 18	130 ± 19
Farm C	57	Jersey	Tie Stall	161 ± 138	66 ± 12
Farm D	465	Holstein	Free Stall	76 ± 28	108 ± 12

Table 2. The effect of THI and minutes that THI ≥ 68 on lying time (hours/day) and lying bouts for each farm, NNY Dairy Cow Heat Stress Study, 2017.

	COOL	HOT	SE	*P*-value
THI (mean ± SD)	60.9 ± 3.7	72.3 ± 1.1	-	-
Minutes THI ≥ 68 (mean ± SD)	74 ± 127	1279 ± 155	-	-
Lying Time (hours/day)				
Farm A	12.8	10.3	0.34	**<0.001**
Farm B	11.5	10.3	0.31	**<0.001**
Farm C	12.8	11.1	0.34	**<0.001**
Farm D	10.3	8.6	0.30	**<0.001**
Lying Bouts (bouts/day)				
Farm A	8.9	9.5	0.53	**0.019**
Farm B	13.7	13.5	0.71	0.751
Farm C	8.6	8.8	0.36	0.400
Farm D	8.3	8.0	0.51	0.229

Table 3. R^2 values for prediction of bulk tank milk yield and components from temperature and relative humidity, NNY Dairy Cow Heat Stress Study, 2017.

Component	Farm A	Farm B	Farm C	Farm D
Bulk Tank Milk Yield	0.00	0.11	0.00	0.00
Fat	0.00	0.00	0.00	0.00
Protein	0.32	0.00	0.00	0.09
Milk Urea Nitrogen	0.00	0.00	0.00	0.00
De Novo Fatty Acids (g/100g milk)	0.00	0.00	0.00	0.00
Mixed Fatty Acids (g/100g milk)	0.00	0.00	0.00	0.00
Preformed Fatty Acids (g/100g milk)	0.19	0.00	0.00	0.00