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# Cow behaviour and milk yield during different categories temperature-humidity indices

## Comportamiento de las vacas y producción de leche durante diferentes categorías de índices de temperatura-humedad

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## ABSTRACT

The goal of this investigation was to study the influence of different values of Temperature-Humidity index (THI) on the duration of lying down and feed consumption, productivity, and heat production by dairy cows in two variants of feedlots (with and without shelters). The study was conducted from February 2007 to early August 2021 in the central part of Ukraine (Kyiv region) in different periods of THI. This index was divided into three categories: 1) 66–71: normal (14 days); 2) 72–79: alert (11 days); 3) $\geq$80: dangerous (9 days). Two variants of feedlots were selected: Open feedlot with shelters and open feedlot without shelters. The largest increase in values of THI affecting the cows was observed in open feedlots without shelters. There, in alert and danger periods duration of feed consumption decreased by 8.0 and 23.1 min, lying down by 17 and 38 min, productivity by 2.3 kg (or 8.77%) and 3.6 kg (or 13.74%), energy consumption by 4.7 and 9.6 MJ, respectively, in comparison to normal period.

**Key words:** dairy cows, feedlots, heat stress, productivity, cows' welfare

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## Resumen

El objetivo del estudio fue evaluar la influencia de diferentes valores de Índice temperatura-humedad (IHT) sobre el tiempo de reposo y el consumo de alimento, la productividad y la producción de calor de las vacas lecheras en dos variantes de *feedlots* (con y sin refugio). El estudio se llevó a cabo desde febrero de 2007 hasta principios de agosto de 2021 en la parte central de Ucrania (región de Kiev) en diferentes períodos de IHT. El índice se dividió en tres categorías: 1) 66–71: normal (14 días); 2) 72–79: alerta (11 días); 3) >80: peligroso (9 días). Se seleccionaron dos variantes de *feedlots*: abierto con sombra y abierto sin sombra. El mayor aumento en los valores de IHT que afectaron a las vacas se observó en los corrales de engorda abiertos sin sombras. Allí, en periodos de alerta y peligro, la duración del consumo de alimento disminuyó en 8.0 y 23.1 min, acostado en 17 y 38 min, la productividad en 2.3 kg (o 8.77%) y 3.6 kg (o 13.74%), el consumo de energía en 4.7 y 9.6 MJ, respectivamente, en comparación con el periodo normal.


**Palabras clave:** vacas lecheras, corrales de engorde, estrés por calor, productividad, bienestar de las vacas

## Introduction

During global warming period and climate change, which are accompanied by an increase livestock numbers and intensification of agriculture (Polsky and Keyserlingk, 2017; Hempel *et a*l., 2019; Borshch *et al*., 2022b), issues related to overcoming the consequences of heat stress becomes increasingly relevant (De Palo *et al*., 2006; Brügemann *et al*., 2011; Nguyen *et al*., 2017).

One of the major challenges in milk production during warm seasons is the increased thermal stress experienced by dairy cows. This is a result of specific environmental conditions, where high temperatures and humidity make it difficult for cows to regulate their body temperature effectively (Segnalini *et al*., 2013; Bertocchi *et al*., 2014; Schüller *et al*., 2014). Dikmen and Hansen (2009) have suggested that the threshold temperature and humidity at which dairy cows begin to show signs of heat stress is 28 °C and 50%, respectively.

During the heat load period the dairy cows increase respiration rate to reduce their own body temperature, while the duration of feed consumption and productivity are decreased (Brown-Brandl *et al*., 2005; Curtis *et al*., 2017; Tousova *et al*., 2017). Animals create a large amount of metabolic heat and accumulate additional heat from radiant energy, which leads to an increase heat load on the body and, as a result, a decrease dry matter intake and productivity loss (Kadzere *et al*., 2002; Ruban *et al*., 2020; Lutsenko *et al*., 2021; Demir and Yazgan, 2023).

Dairy cows are particularly vulnerable to heat stress compared to other mammals, as they generate more metabolic heat due to the fermentation processes that occur in their rumen (Bernabucci *et al*., 2014). Additionally, milk production in cows result in an increase in internal heat loads (Chebel *et al*., 2004; Aharoni *et al*., 2005), further exacerbating the impact of heat stress on these animals.

The measurement of animal welfare and comfort is of utmost importance (Mattachini *et al*., 2011), as it directly influences various aspects of dairy cow health and productivity, including their resting behavior, hormonal status (Skliarov *et al*., 2022), metabolic changes, and milk production (Veèeøa *et al*., 2016). Thus, indicators of animal welfare and comfort serve as essential tools for evaluating and optimizing the overall management and well-being of dairy cows (Angrecka and Herbut, 2017).

According to different variants animal housing to the main phenotypic traits of animal comfort include behavioral indicators (Angrecka and Herbut, 2016; Borshch *et al*., 2021, 2022a). Dairy cattle behavior varies substantially depending on ambient temperature and temperature-humidity index (THI) (De Palo *et al*., 2005; Segnalini *et al*., 2013; Galan *et al*., 2018). To address the challenges of heat stress in dairy cows, it is necessary to implement various planning, structural, and technical solutions for cattle housing facilities, including modifications to buildings, cooling systems, and management practices (Yi *et al*., 2018; Borshch *et al.,* 2019). The implementation of various measures such as light curtains, ridge vents for ventilation, open feedlots equipped with shelters, irrigation and ventilation systems, and dual-chamber waterbeds to facilitate cow rest can effectively mitigate heat stress (Vasseur *et al*., 2012; Mondaca *et al*., 2013; Menconi and Grohmann, 2014).

The goal of this investigation was to study the influence of different values of THI on the duration of lying down and feed consumption, productivity, and heat production by dairy cows in two variants of feedlots (with and without shelters).

## MATERIALS AND METHODS

The research was conducted from February 2007 to early August 2021 in the central part of Ukraine (Kyiv region) in different periods of temperature-humidity index (THI). This index was divided into three categories: 1) 66–71 is normal (14 days), 2) 72–79 is alert (11 days) and 3) 80 or more is dangerous (9 days).

Table 1 summarizes the key environmental factors that were measured across different phases of the study. Farm with two variants feedlots was selected for analysis.

- The first variant – open feedlot with shelters (72×25 m. An exercise area of 20 $m^2$ per individual, including shelter area of 5 $m^2$ per individual). The surface of the exercise area is made of soil and has an even relief. There are four group drinking bowls along the perimeter of feedlot.

Table 1. Environmental indicators under different Temperature-humidity index (THI) in two variants of feedlots

| Indicators | | THI | | |
|---|---|---|---|---|
| | | Normal | Alert | Danger |
| Temperature (°C): | Feedlot with shelters | 20.6 | 25.8 | 29.4 |
| | Feedlot without shelters | 21.1 | 26.6 | 31.6 |
| Relative humidity (%) | Feedlot with shelters | 65.7 | 55.1 | 63.1 |
| | Feedlot without shelters | 65.4 | 55.7 | 57.8 |
| Wind speed (m/s) | Feedlot with shelters | 2.2 | 2.6 | 2.8 |
| | Feedlot without shelters | 2.3 | 2.6 | 2.8 |

- The second variant – open feedlots without shelters (100×120 m. An exercise area of 59.5 $m^2$ per individual). The surface of the exercise area is unpaved and has sloping sections (tilt angle up to 2°). Two group drinking bowls are in the center of the feedlot and in the feeding area.

At the farm, cows are fed with a total mixed ration throughout the year. Each cow intake between 21.4 to 21.8 kg of dry matter per day. The consumed fodder had an energy value of 211 to 220 MJ, and the energy concentration in each kilogram of dry matter is between 10.3 to 10.4 MJ.

Second lactating Holstein cows during the period of maximum productivity (2–3 months of lactation) were selected. The first feedlot variant had 34 cows and the second feedlot variant: 32 cows. The THI was calculated according to Dikmen and Hansen, 2009: $THI = (1.8 \times T_{air} + 32) - (0.55 – 0.0055 \times RH) \times (1.8 \times T_{air} - 26.8)$, where $T_{air}$ – air temperature, °C; RH – relative humidity, %.

The Equivalent Temperature Index for Cattle (ETIC, °C) was calculated according to Wang *et al.,* 2018: ETIC = T - 0.0038 × T × (100 - RH) - 0.1173 × |v|0.707 × (39 × 20 - T) + 1.86 × 10-4 × T × Q, where v – air velocity, $m/s^{-1}$; Q – solar radiation, $Wm^{-2}$. ETIC was divided into four categories: 1) mild stress (18<–<20); 2) moderate stress (20≤–<25); 3) severe stress (25≤–<32); 4) emergency (e≥32).

The Equivalent Thermal Index (ETI, °C) was calculated according to Baeta *et al.,* 1987 as follows: $ETI = 27.88 - 0.456 \times T_{air} + 0.010754 \times T_{air}^2 - 0.49505 \times RH + 0.00088 \times RH^2 + 1.1507 \times WS - 0.126447 \times WS^2 + 0.019876 \times T_{air} \times RH - 0.046313 \times T_{air} \times WS$, where WS – average wind speed (m/s).

ETI values are considered as representing a damaging risk to animals: no problem: 18 °C to <27 °C; caution: 27 °C to <32 °C; extreme caution: 32 °C to <38 °C; danger: 38 °C to <44 °C; extreme danger: ≥44 °C (Gosling *et al*., 2014).

The behavior of cattle was monitored using indoor security cameras. A total of eight Full HD Hikvision cameras were strategically placed around the perimeter of the feedlot with shelters, while 12 cameras were deployed around the feedlot without shelters. The cameras were set to record continuously for 24 hours, capturing footage of the sheds, rest areas, and manger spaces. Daily observations of the manger space were conducted during each period of THI from 10:00 to 19:00 hours (peak temperature load). At regular 10-minute intervals, the number of cows eating, lying down, and standing was recorded in the experimental groups.

Temperature and relative humidity levels were monitored by a Voltcraft DL-141 sensor (Germany) capable of measuring temperatures ranging from -40 to +70 °C and relative humidity levels between 0 to 100%. Sensors were placed 0.5 m above the floor and readings were automatically recorded every 10 minutes. Wind speed inside the barn was determined by a handheld pocket digital anemometer AZ-8919 model from AZ (Taiwan). Solar radiation levels were measured by radiometer RÀÒ-2P-F (Ukraine). The cows' skin surface temperature was measured in two locations: on the rumen and in the region of the last intercostal space, using a remote infrared thermometer (Thermo SpotPlus from Germany).

Indicators of wind speed inside the barns, solar radiation and temperature of the surface of the skin of cows were daily determined from 10.00 to 19.00 in different periods of the THI. Costs of energy for heat production in different periods of THI were calculated according to the methods of Kadzere *et al.* (2002).

Data are reported as means ± standard error of the mean. To assess the statistical significance of the obtained values, Student's *t*-test was employed, and data were consi-

Table 2. Average feed intake of dairy cattle and rest in a lying position by different values of Temperature-humidity index (THI)

| Behavior indicators | | THI | | |
|---|---|---|---|---|
| | | Normal | Alert | Danger |
| Duration of feed consumption (min) | Feedlot with shelters | 187.3±6.3 | 177.1±5.8 | 170.5±4.4 |
| | Feedlot without shelters | 182.6±5.3 | 174.6±4.9 | 159.5±3.2[a] |
| Lying time (min) | Feedlot with shelters | 312.7±6.0 | 301.3±5.1 | 286.8±4.4 |
| | Feedlot without shelters | 304.1±6.4 | 287.2±4.7[a] | 266.5±4.1[b] |

[a]P<0.05; [b]P<0.01 as compared with feedlot with shelters

dered significant at [a]P<0.05, [b]P<0.01, [c]P<0.001. A Student's *t*-test was performed to compare the average between the feedlot without shelters and the feedlot with shelters. All statistical analyses were conducted by the Statistica software (v. 11.0, 2012).

## Results and Discussion

The indicators that not only form the level of daily milk productivity, but also indicate the structural and space-planning features of cows housing option and their comfort are indicators of the duration of feed consumption, number of approaches to the manger and average duration of one feed consumption.

The duration of feed consumption increased in both type of feedlots when the indicators of THI decreased (Table 2). On this, the greatest difference was between THI normal and alert and between normal and danger (8.0 and 23.1 min, respectively) was observed in cows in open feedlots without shelters. On the other hand, the duration of feed consumption decreased by 10.2 minutes during alert period and by 16.8 minutes during dangerous period of feedlot with shelters as compared to the normal period.

The indicator of duration cows rest in a lying position is one of the main ethological indicators, which indicates on comfort of housing conditions and has a direct connection with milk yield in 24 hours. At the normal value of THI, the longer cows rest lying down was 312 min by feedlot with shelters and slightly less time (304 min) in feedlot without shelters. The reduction time in lying position during alert categories of THI was 11.4 and 16.9 min on feedlot with shelters and without shelters respectively. A more significant reduction of lying position period occurred at a dangerous value THI in feedlot with shelters (25.9 min) and feedlot without shelters (37.6 min).

The shorter duration of feed consumption during heat stress periods correspond to results published by West (2003). The results of this study overlap with the results shown by Brown-Brandl *et al.* (2005), which established dependence between heat stress category and duration of feed consumption and number of meals consumed by animals housing on open feedlots with and without shelters. Moreover, the results correspond with data by Kanjanapruthipong *et al.* (2015) and Herbut and Angrecka (2018) indicating a decrease in total time to cows rest in lying position during heat stress periods.

Heat load (heat stress) on the body of dairy cattle is one of the factors that has a significant economic impact on milk production. The greatest productivity losses were 2.3 kg (8.77%) and 3.6 kg (13.74%) in cows on feedlot without shelters during alert and dangerous periods of THI (Table 3). When keeping cows in feedlot with shelters

Table 3. Milk yield and energy consumption in cows by different values of Temperature-humidity index (THI)

| Indicators | | THI | | |
|---|---|---|---|---|
| | | Normal | Alert | Danger |
| Milk yield (kg) | Feedlot with shelters | 26.6±0.24 | 24.9±0.37 | 23.9±0.26 |
| | Feedlot without shelters | 26.2±0.18 | 23.9±0.25[a] | 22.6±0.37[b] |
| Energy consumption of heat production, (MJ) | Feedlot with shelters | 65.1±0.59 | 67.8±0.33 | 72.0±0.53 |
| | Feedlot without shelters | 64.6±0.78 | 69.3±0.41[b] | 74.2±0.48[b] |

[a]P<0.05; [b]P<0.01 as compared with feedlot with shelters

Table 4. Average of the Equivalent Thermal Index (ETI) and the Equivalent Temperature Index for Cattle (ETIC) indicators by different values of Temperature-humidity index (THI)

| Behavior indicators | | THI | | |
|---|---|---|---|---|
| | | Normal | Alert | Danger |
| ETI (°C) | Feedlot with shelters | 21.04±0.16 | 25.95±0.24 | 38.03±0.47 |
| | Feedlot without shelters | 21.59±0.22[a] | 26.89±0.29[a] | 39.74±0.44[b] |
| ETIC (°C) | Feedlot with shelters | 14.14±0.19 | 18.36±0.24 | 23.06±0.31 |
| | Feedlot without shelters | 14.52±0.29 | 19.25±0.33[a] | 25.05±0.37[c] |

[a]P<0.05; [b]P<0.01 as compared with feedlot with shelters

productivity losses in alert and dangerous categories of THI were 1.7 kg (6.39%) and 2.7 kg (10.15%) respectively. Similar results were obtained by Smith *et al*. (2013) in Mississippi State (USA), which indicate a decrease in the dynamics of daily milk yield of Holstein cows during heat stress period.

The results confirmed that increasing ambient temperature and, consequently, THI have affected to increase by energy consumption to heat transfer. In feedlots with shelters, energy consumption increased by 2.7 MJ during the THI alarm period and during the THI danger period by 6.9 MJ compared to the normal THI value. During the heat load period, higher energy consumption was observed in feedlots without shelters during the alert period, as THI value increased by 4.7 MJ, while the THI increased by 9.6 MJ during the dangerous period. These results agreed with Kadzere *et al*. (2002) which indicated that during temperature loads periods (heat or cold stress) energy consumption increasing in lactating cows.

The equivalent temperature index (ETI) and the equivalent temperature index for cattle (ETIC) were used to study the effect of THI on the comfort of cows according to variants of housing (Table 4). ETI indicators increased in both type of feedlots during alert and dangerous periods of THI values. However, during alert period of THI are observed no problem values of ETI. During alarm period of THI the values of ETIC were in range of mild stress by all feedlots variants. At the ETIC indicators in dangerous period of THI in feedlot with shelters values was refer in range of moderate stress (23.06), whereas in feedlot without shelters the values was refer in range of severe stress (25.05).

## Conclusions

- An increase of THI indicator became a significant stress factor, which significantly affected the duration of feed consumption and lying down, productivity, energy consumption, and the values of Equivalent Thermal Index (ETI) and the Equivalent Temperature Index for Cattle (ETIC) in both type of cow housing.
- The best indicators of productivity and energy consumption, and values of ETI and ETIC during alert and dangerous periods of THI were marked due to a longer stay of cows in comfort zone (shadow) when housing cows on open feedlots with shelters in compared to open feedlots without shelters.

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