CHAPTER «VETERINARY COMMUNICATIONS»

PREDICTION OF COMFORT FOR DAIRY COWS, DEPENDING ON THE STATE OF THE ENVIRONMENT AND THE TYPE OF BARN

Mylostyvyi Roman[1]
Chernenko Oleksandr[2]
Lisna Alisa[3]

DOI: https://doi.org/10.30525/978-9934-571-78-7_53

Abstract. Material and resource conservation are important when choosing the optimal technology for keeping dairy cattle. The so-called "Canadian technologies" of frame construction that are widely used in the world are only relatively recently used in national animal husbandry. The question of ensuring the comfort of animals in such rooms remains controversial, since the climate in them is as close as possible to environmental conditions. The purpose of the study was to study the temperature and humidity regime of uninsulated rooms and assess the state of comfort of animals in barns of the frame and hangar type. The temperature and humidity of the air were measured inside and outside the premises (n = 827) periodically from January to July 2018 (in the temperature range from -7.8 to +34.2°C). Using the multiple linear regression function in STATISTICA 10 (StatSoft, Inc., 2011), the calculated temperature values in the barns for low and high temperatures of the Steppe of Ukraine were obtained. It has been established that the temperature-humidity regime of uninsulated rooms is as close as possible to the state of the external environment and depends on the design features (type) of the barn.

[1] Candidate of Veterinary Sciences, Associate Professor,
Associate Professor of the Department of Technology for Processing Livestock Products,
Dnipro State Agrarian and Economic University, Ukraine
[2] Doctor of Agricultural Sciences, Associate Professor,
Professor of the Department of Technology of Animal Feeding and Breeding,
Dnipro State Agrarian and Economic University, Ukraine
[3] Postgraduate Student,
Dnipro State Agrarian and Economic University, Ukraine

The temperature difference inside and outside the premises will be 3-5°C. It is necessary to provide additional space cooling (axial fans of large diameter, small-drop irrigation, as well as their combination), since the temperature-humidity index (THI) inside the barn will be 2-3 units higher. The material of the article will be useful for breeders when choosing a technology for keeping dairy cows. Calculated values of temperatures and THI in uninsulated rooms of frame and hangar type can be used as approximate data for assessing the comfort of cows in lightweight rooms in conditions of temperate continental climate of the Steppe of Ukraine. The values of temperature and relative humidity of air in the barns obtained by us, as well as the temperature-humidity index (as an indicator of the comfort of animals in hot conditions), require practical confirmation under conditions of extreme high and low ambient temperatures. This will be the material for our further research, as well as the influence of climate in the barn on the physiological state and productivity of dairy cows.

1. Introduction

The environment has a significant impact on the physiological state, behavior and productivity of dairy cows [25, p. 1; 26, p. 705; 28, p. 1623]. This should be taken into account when creating comfortable conditions for animals, protecting them from extreme high and low temperatures [2, p. 81]. The boundaries of temperature comfort for livestock are very small and depend on the breed and animal productivity [12, p. 1675]. Comfortable for cows are temperatures from +5 to +20°C [5, p. 5]. According to some data, temperatures ranging from -34°C [1, p. 481] to +25°C [22, p. 2407] will be acceptable for livestock. In any case, only in good conditions animals can fully realize their productive potential.

The way of keeping dairy cows in each case is selected based on climatic, economic and industrial conditions. In Ukraine, capital buildings (cowsheds) are mainly built for keeping livestock in the cold period of the year and light canopies to protect animals from heat and precipitation during grazing. And only in recent decades, frame construction of premises made of metal structures has become widespread in animal husbandry. Such modern wide-sized barns are equipped with side curtains, aft table, cow boxes and a light-emitting comb [21, p. 41]. Researchers [33, p. 74] believe that they are most comfortable for highly productive animals when kept in barns all year round.

The microclimate of such premises largely depends on the environmental conditions. Moreover, the temperature difference inside and outside the barn is minimal [13, p. 25; 21, p. 41; 24, p. 305] and they directly affect animals [2, p. 81]. Reports by authors [21, p. 41; 32, p. 37; 35, p. 225] are only partially devoted to the study of climate in uninsulated rooms. They cover, as a rule, only one of the seasons of the year, taking into account short-term measurements of the state of the air environment in the barn. This limits the ability to build accurate mathematical models of climate prediction in animal rooms due to a small sample.

The one-sided approach remains to assessing the influence of air on the physiological state and productivity of cows. Since the temperature and relative humidity of the air are taken into account without their joint influence on the organism of animals. Whereas the temperature and humidity index (THI) has long been considered to be a fairly reliable criterion for assessing the comfort of animals [9, p. 1]. At the same time, the ongoing search for new solutions to assess the impact of the external environment on the welfare of dairy cattle continues [10].

The aim of the work was to assess the state of animal comfort in uninsulated cowsheds of various types in a temperate climate of the Steppe of Ukraine. This involved multiple measurements of temperature and relative humidity of air outside and inside barns (for building linear regression models), forecasting temperature and humidity in rooms at high and low ambient temperatures, and calculating the value of temperature-humidity index in rooms as a criterion for evaluating comfort cows in heat.

2. Materials and methods

The study was conducted in cowsheds of a monoblock dairy complex of the private joint-stock company Agro-Soyuz of the Dnipropetrovs'k region from January to June 2018. The temperature and humidity conditions of different types of rooms were studied. The cowshed carcass type (CCT) is made of metal structures (without roof insulation), and in a cowshed hangar type (CHT) with a canopy in the form of an awning (Figure 1).

These wide-sized cowsheds have side tarpaulin curtains, they have, respectively, six- and four-row stalls for dairy cows without a leash. The premises are equipped with aft tables and group automatic drinkers. The design features of these premises are described in detail earlier [33, p. 74]. The temperature and relative humidity of the air were measured

a b c

Figure 1. Monoblock of the dairy complex with uninsulated rooms of different types (*a* – the appearance of the dairy complex; *b* – cowshed carcass type; *c* – cowshed hangar type)

by a professional Benetech GM 1360 thermohygrometer outside and inside the CCT (n = 334) and CHT (n = 493) in the sides and central stall at the level of animal rest. The state of the environment at the location of the dairy complex during the heat was predicted on the basis of historical data from the meteorological report for 2017 (https://meteo.ua/). The measurements were carried out taking into account the temperature and humidity of the air at a time (n = 1924) within the temperature range of +20 ... + 37°C. The data obtained were used to construct linear regression models using the built-in statistical functions of the STATISTICA 10 software (StatSoft, Inc., 2011).

3. Climate prediction in uninsulated cowsheds of different types depending on the state of the environment

The data obtained indicate that the climate in the barns is directly dependent on the state of the external environment. Outside air temperatures during the study period varied from -7.5°C to +34.2°C. The correlation between temperature and relative humidity outside and inside CCT was respectively r = 0.997 (R^2 = 0.99) and r = 0.955 (R^2 = 0.91) (P <0.01). The relationship between temperature and humidity inside the CHT and outside was respectively r = 0.997 (R^2 = 0.99) and r = 0.965 (R^2 = 0.93) (P <0.01). This made it possible to predict the temperature and humidity conditions in uninsulated barns of various types (Table 1 and Table 2).

In this case, the linear regression equations for calculating the temperature and relative humidity of air in uninsulated cowsheds of various types were such

$$T_{CCT} = 2.532533 + 0.878064 \times T \quad (1)$$

$$RH_{CCT} = 15.03246 + 0.77416 \times RH \quad (2)$$

$$T_{CHT} = 2.103149 + 0.902499 \times T \quad (3)$$

$$RH_{CHT} = 6.107011 + 0.922974 \times RH \quad (4)$$

where T_{CCT} – temperature in the cowshed carcass type, °C
T_{CHT} – temperature in the cowshed hangar type, °C
RH_{CCT} – relative humidity in the cowshed carcass type, %
RH_{CHT} – relative humidity in the cowshed hangar type, %
T – ambient temperature, °C
RH – ambient relative humidity, %

Estimates suggest that the temperature in the premises of lightweight construction as close as possible to the indicators of the external environment (Fig. 2). The difference between external and internal temperatures in conditions of the lowest possible ambient temperature (-25°C), depending on the type of cowshed, will be from 4.5 to 5.6°C. In conditions of heat (+46°C), the temperature difference will be from 2.4 to 3.1°C. At a temperature of +21.0–22.0°C, the temperature inside and outside the premises will be the same.

Therefore, the design features of the of the rooms carcass and hangar type contribute to the preservation of the air temperature in the cowsheds when lowering the external temperatures below +21.0°C and, conversely, as they rise above +22.0°C, the roof of the barns acts as a shadow protection of animals from direct sunlight and contributes to maintaining coolness.

The relative humidity inside the rooms to a greater extent than the temperature will depend on the design features of the rooms. It is calculated that the difference in this indicator between the environment and CCT will

Table 1

Calculated values of temperature in cowsheds of various types depending on external temperature

T	Cowshed carcass type, n=334		Cowshed hangar type, n=493		T	Cowshed carcass type, n=334		Cowshed hangar type, n=493	
	T_{CCT}	+/- toward T	T_{CHT}	+/- toward T		T_{CCT}	+/- toward T	T_{CHT}	+/- toward T
-25	-19.4	+5.6	-20.5	+4.5	11	12.2	+1.2	12.0	+1.0
-24	-18.5	+5.5	-19.6	+4.4	12	13.1	+1.1	12.9	+0.9
-23	-17.7	+5.3	-18.7	+4.3	13	13.9	+0.9	13.8	+0.8
-22	-16.8	+5.2	-17.8	+4.2	14	14.8	+0.8	14.7	+0.7
-21	-15.9	+5.1	-16.8	+4.2	15	15.7	+0.7	15.6	+0.6
-20	-15.0	+5.0	-15.9	+4.1	16	16.6	+0.6	16.5	+0.5
-19	-14.2	+4.8	-15.0	+4.0	17	17.5	+0.5	17.4	+0.4
-18	-13.3	+4.7	-14.1	+3.9	18	18.3	+0.3	18.3	+0.3
-17	-12.4	+4.6	-13.2	+3.8	19	19.2	+0.2	19.3	+0.3
-16	-11.5	+4.5	-12.3	+3.7	20	20.1	+0.1	20.2	+0.2
-15	-10.6	+4.4	-11.4	+3.6	21	21.0	0.0	21.1	+0.1
-14	-9.8	+4.2	-10.5	+3.5	22	21.8	-0.2	22.0	0.0
-13	-8.9	+4.1	-9.6	+3.4	23	22.7	-0.3	22.9	-0.1
-12	-8.0	+4.0	-8.7	+3.3	24	23.6	-0.4	23.8	-0.2
-11	-7.1	+3.9	-7.8	+3.2	25	24.5	-0.5	24.7	-0.3
-10	-6.2	+3.8	-6.9	+3.1	26	25.4	-0.6	25.6	-0.4
-9	-5.4	+3.6	-6.0	+3.0	27	26.2	-0.8	26.5	-0.5
-8	-4.5	+3.5	-5.1	+2.9	28	27.1	-0.9	27.4	-0.6
-7	-3.6	+3.4	-4.2	+2.8	29	28.0	-1.0	28.3	-0.7
-6	-2.7	+3.3	-3.3	+2.7	30	28.9	-1.1	29.2	-0.8
-5	-1.9	+3.1	-2.4	-2.6	31	29.8	-1.2	30.1	-0.9
-4	-1.0	+3.0	-1.5	+2.5	32	30.6	-1.4	31.0	-1.0
-3	-0.1	+2.9	-0.6	+2.4	33	31.5	-1.5	31.9	-1.1
-2	0.8	+2.8	0.3	+2.3	34	32.4	-1.6	32.8	-1.2
-1	1.7	+2.7	1.2	+2.2	35	33.3	-1.7	33.7	-1.3
0	2.5	+2.5	2.1	+2.1	36	34.1	-1.9	34.6	-1.4
1	3.4	+2.4	3.0	+2.0	37	35.0	-2.0	35.5	-1.5
2	4.3	+2.3	3.9	+1.9	38	35.9	-2.1	36.4	-1.6
3	5.2	+2.2	4.8	+1.8	39	36.8	-2.2	37.3	-1.7
4	6.0	+2.0	5.7	+1.7	40	37.7	-2.3	38.2	-1.8

End of the Table 1

T	Cowshed carcass type, n=334		Cowshed hangar type, n=493		T	Cowshed carcass type, n=334		Cowshed hangar type, n=493	
	T_{CCT}	+/- toward T	T_{CHT}	+/- toward T		T_{CCT}	+/- toward T	T_{CHT}	+/- toward T
6	7.8	+1.8	7.5	+1.5	42	39.4	-2.6	40.0	-2.0
7	8.7	+1.7	8.4	+1.4	43	40.3	-2.7	40.9	-2.1
8	9.6	+1.6	9.3	+1.3	44	41.2	-2.8	41.8	-2.2
9	10.4	+1.4	10.2	+1.2	45	42.0	-3.0	42.7	-2.3
10	11.3	+1.3	11.1	+1.1	46	42.9	-3.1	43.6	-2.4

Note. T – ambient air temperature (° C); TCCT – air temperature in the cowshed carcass type (°C); TCHT – air temperature in the cowshed hangar type (°C).

Table 2

Calculated values of relative humidity in different types of cowsheds depending on the humidity of the outside air

RH	Cowshed carcass type, n=334		Cowshed hangar type, n=493		RH	Cowshed carcass type, n=334		Cowshed hangar type, n=493	
	RH_{CCT}	+/- toward RH	RH_{CHT}	+/- toward RH		RH_{CCT}	+/- toward RH	RH_{CHT}	+/- toward RH
17	28.2	+11.2	21.8	+4.8	59	60.7	+1.7	60.6	+1.6
18	29.0	+11.0	22.7	+4.7	60	61.5	+1.5	61.5	+1.5
19	29.7	+10.7	23.6	+4.6	61	62.3	+1.3	62.4	+1.4
20	30.5	+10.5	24.6	+4.6	62	63.0	+1.0	63.3	+1.3
21	31.3	+10.3	25.5	+4.5	63	63.8	+0.8	64.3	+1.3
22	32.1	+10.1	26.4	+4.4	64	64.6	+0.6	65.2	+1.2
23	32.8	+9.8	27.3	+4.3	65	65.4	+0.4	66.1	+1.1
24	33.6	+9.6	28.3	+4.3	66	66.1	+0.1	67.0	+1.0
25	34.4	+9.4	29.2	+4.2	67	66.9	-0.1	67.9	+0.9
26	35.2	+9.2	30.1	+4.1	68	67.7	-0.3	68.9	+0.9
27	35.9	+8.9	31.0	+4.0	69	68.4	-0.6	69.8	+0.8
28	36.7	+8.7	32.0	+4.0	70	69.2	-0.8	70.7	+0.7
29	37.5	+8.5	32.9	+3.9	71	70.0	-1.0	71.6	+0.6
30	38.3	+8.3	33.8	+3.8	72	70.8	-1.2	72.6	+0.6
31	39.0	+8.0	34.7	+3.7	73	71.5	-1.5	73.5	+0.5
32	39.8	+7.8	35.6	+3.6	74	72.3	-1.7	74.4	+0.4
33	40.6	+7.6	36.6	+3.6	75	73.1	-1.9	75.3	+0.3

End of the Table 2

RH	Cowshed carcass type, n=334		Cowshed hangar type, n=493		RH	Cowshed carcass type, n=334		Cowshed hangar type, n=493	
	RH_{CCT}	+/- toward RH	RH_{CHT}	+/- toward RH		RH_{CCT}	+/- toward RH	RH_{CHT}	+/- toward RH
35	42.1	+7.1	38.4	+3.4	77	74.6	-2.4	77.2	+0.2
36	42.9	+6.9	39.3	+3.3	78	75.4	-2.6	78.1	+0.1
37	43.7	+6.7	40.3	+3.3	79	76.2	-2.8	79.0	0.0
38	44.5	+6.5	41.2	+3.2	80	77.0	-3.0	79.9	-0.1
39	45.2	+6.2	42.1	+3.1	81	77.7	-3.3	80.9	-0.1
40	46.0	+6.0	43.0	+3.0	82	78.5	-3.5	81.8	-0.2
41	46.8	+5.8	43.9	+2.9	83	79.3	-3.7	82.7	-0.3
42	47.5	+5.5	44.9	+2.9	84	80.1	-3.9	83.6	-0.4
43	48.3	+5.3	45.8	+2.8	85	80.8	-4.2	84.6	-0.4
44	49.1	+5.1	46.7	+2.7	86	81.6	-4.4	85.5	-0.5
45	49.9	+4.9	47.6	+2.6	87	82.4	-4.6	86.4	-0.6
46	50.6	+4.6	48.6	+2.6	88	83.2	-4.8	87.3	-0.7
47	51.4	+4.4	49.5	+2.5	89	83.9	-5.1	88.3	-0.7
48	52.2	+4.2	50.4	+2.4	90	84.7	-5.3	89.2	-0.8
49	53.0	+4.0	51.3	+2.3	91	85.5	-5.5	90.1	-0.9
50	53.7	+3.7	52.3	+2.3	92	86.3	-5.7	91.0	-1.0
51	54.5	+3.5	53.2	+2.2	93	87.0	-6.0	91.9	-1.1
52	55.3	+3.3	54.1	+2.1	94	87.8	-6.2	92.9	-1.1
53	56.1	+3.1	55.0	+2.0	95	88.6	-6.4	93.8	-1.2
54	56.8	+2.8	55.9	+1.9	96	89.4	-6.6	94.7	-1.3
55	57.6	+2.6	56.9	+1.9	97	90.1	-6.9	95.6	-1.4
56	58.4	+2.4	57.8	+1.8	98	90.9	-7.1	96.6	-1.4
57	59.2	+2.2	58.7	+1.7	99	91.7	-7.3	97.5	-1.5
58	59.9	+1.9	59.6	+1.6	100	92.4	-7.6	98.4	-1.6

Note. RH – ambient air relative humidity (%); RHCCT – air relative humidity in the cowshed carcass type (%); RHCHT – air relative humidity in the cowshed hangar type (%).

be from 6.0 to 11.2%, and CHT from 1.6 to 4.8%. With an increase in the relative humidity of the environment to 66.0–78.0%, this indicator in the rooms will be higher than outside. Above these values and up to the maximum (100%) saturation of external air with water vapor, the relative humidity in the cowsheds will remain below external indicators.

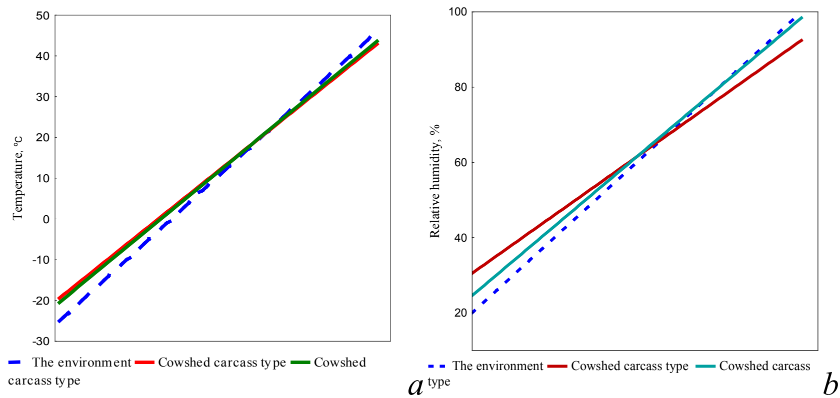

Figure 2. The dependence of temperature (*a*) and humidity (*b*) in different types of rooms on the state of the environment

Therefore, the temperature and humidity conditions in the rooms of uninsulated type depend on the external environment and depend on the design features of the rooms, which can affect the state of comfort of animals.

4. Assessment of the state of comfort of dairy cows using a temperature-humidity index

Temperature and humidity conditions in uninsulated cowsheds are close to environmental conditions. The difference between external and internal temperature in such rooms is insignificant. According to scientists [21, p. 41; 32, p. 37; 35, p. 225], during the transitional and hot period of the year, it is up to 5 ° C. In the cold period of the year, water and manure can freeze in an uninsulated cowshed, incapacitate machinery and equipment fail [13, p. 25]. Our research and direct presence in the premises (in cold and heat), confirm the data obtained by the authors.

A more serious problem is high air temperatures, to which dairy cows are very sensitive [7, p. 260; 11, p. 37]. The heat causes a change in the clinical state of animals [4, p. 4939], impaired metabolic homeostasis [8, p. 1244], a decrease in milk yield in cows [15, p. 319; 27, p. 2017; 30, p. 40; 31, p. 97].

The temperature-humidity index (THI) is used to assess the effect of heat on dairy cattle [34, p. 165]. The methods for calculating it are very diverse [3, p. 1947], as is the degree of heat stress that he characterizes [10]. However, among researchers the calculation of THI is not widely used. This is not available in our literature. It was used to assess the effect of heat on dairy cows only in recent studies [29, p. 128]. They indicate a reliable relationship between the temperature and humidity of the air and the milk yield of animals at the barn location. Therefore, the method of calculating the THI [14, p. 862], was used in our research.

Since cattle tolerate lower temperatures more easily than heat, it is important to simultaneously control the high temperatures and relative humidity of the air, which, as is well known, jointly affect the thermoregulation of animals. The state of comfort of the cows was determined by calculating the temperature-humidity index (THI) by the equation

$$THI = 1.8 \times T - (1 - RH / 100) \times (T - 14.3) + 32 \tag{5}$$

where *THI* – temperature-humidity index

T – air temperature, °C

RH – relative humidity, %

Based on the archive records (n = 1924) of air temperature and humidity, a temperature-humidity index was calculated (Table 3), the value of which with a high degree of probability (Fig. 3) can be predicted based on the externals ambient temperatures using the equation

$$THI_{EN} = 46.97807 + 0.96075 \times T \tag{6}$$

where THI_{EN} – temperature-humidity index of the environment

T – ambient air temperature, °C.

Considering the difference between the state of the environment and the climate of the premises, the probable values of the temperature-humidity index in the cowshed carcass type (7) and cowshed hangar type (8) were calculated

$$THI_{CCT} = 47.05419 + 0.99649 \times T \tag{7}$$

$$THI_{CHT} = 46.00549 + 1.04460 \times T \tag{8}$$

where THI_{CCT} temperature-humidity index in the cowshed carcass type

THI_{CHT} – temperature-humidity index in the cowshed hangar type

T – ambient air temperature, °C.

The calculated data (Table 3) indicate a slight difference in the indices of the temperature-humidity index in the uninsulated cowsheds of different

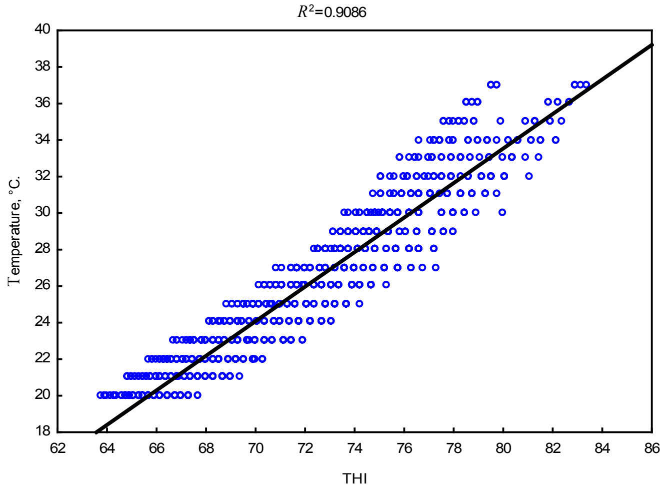

Figure 3. Dependence of temperature-humidity index on ambient air temperature

Table 3

The calculated values of temperature-humidity index, depending on the ambient temperature and the type of room

T	THI_{EN}	THI_{CCT}	THI_{CHT}	T	THI_{EN}	THI_{CCT}	THI_{CHT}
20	66.2	67.0	66.9	33	78.7	79.9	80.5
21	67.2	68.0	67.9	34	79.6	80.9	81.5
22	68.1	69.0	69.0	35	80.6	81.9	82.6
23	69.1	70.0	70.0	36	81.6	82.9	83.6
24	70.0	71.0	71.1	37	82.5	83.9	84.7
25	71.0	72.0	72.1	38	83.5	84.9	85.7
26	72.0	73.0	73.2	39	84.4	85.9	86.7
27	72.9	74.0	74.2	40	85.4	86.9	87.8
28	73.9	75.0	75.3	41	86.4	87.9	88.8
29	74.8	76.0	76.3	42	87.3	88.9	89.9
30	75.8	76.9	77.3	43	88.3	89.9	90.9
31	76.8	77.9	78.4	44	89.3	90.9	92.0
32	77.7	78.9	79.4	45	90.2	91.9	93.0

types (0.1-1.1 units). However, the difference between the THI outside and inside the barns of lightweight construction of 2-3 units, must provide for the adoption of appropriate technical solutions to create comfortable conditions for dairy cattle.

Researchers at Lallemand Animal Nutrition [17, p. 26] also give an equation (5) in their materials. The value of THI below 68 corresponds to comfortable conditions for animals and is the limit above which they are subject to thermal stress. Thus, the value of THI at the level of 68-71 corresponds to a slight stress, within 72-79 to moderate stress, whereas at 80-89, the cows are in a state of strong, and 90-99 – very strong (hard) stress [23, p. 18].

Other Russian authors [5, p. 5], when estimating the degree of manifestation of heat stress, used the following THI calculation (equation 9)

$$THI = 0.72(W + D) + 40.6 \quad (9)$$

where W and D are, respectively, the temperature (°C) of a wet and dry thermometer.

Researchers believe that the index value below 68 indicates that the cow is in the comfort zone, if it ranges from 69 to 72, then this corresponds to the onset of heat stress; a value from 73 to 78 characterizes the development of heat stress. If the indicator is in the range from 79 to 84, then the animal is subject to severe heat stress, and if it is greater than 85, death is possible. However, the simultaneous measurement of the temperature of dry and wet thermometers is not always possible. Therefore, the use of this equation is not very convenient.

The choice of the necessary equation for the calculation of THI depends on the climatic conditions. In a humid climate, it is necessary to use an index with a high specific weight for humidity, whereas higher temperature weights are best for determining heat stress in arid climate [3, p. 1947].

Convenient in assessing the comfort of animals is to use the table of values of THI in terms of temperature and relative humidity. It will look like this (Table 4) taking into account regional climatic features of the location of the dairy complex (Steppe of Ukraine). A similar table is also given by other authors, referring to the scale of temperature stress assessment at the University of Arizona [5, p. 5; 18, p. 32; 19, p. 34].

Between temperature and humidity of the environment in the range from +20 to +37°C (n = 1924) a tight bond was found ($r = -0.60$; $P < 0.01$).

Table 4

Calculated THI values taking into account the regional climatic conditions of the steppe of Ukraine

Temperature, ° C	Relative humidity,%																
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	63	63	64	64	64	65	65	65	65	66	66	66	67	67	67	67	68
21	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69
22	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71
23	66	66	67	67	68	68	69	69	69	70	70	71	71	72	72	73	73
24	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75
25	68	68	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
26	69	69	70	71	71	72	72	73	74	74	75	75	76	76	77	78	78
27	70	70	71	72	72	73	74	74	75	76	76	77	77	78	79	79	80
28	71	71	72	73	73	74	5	76	76	77	78	78	79	80	80	81	82
29	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	83
30	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	84	85
31	74	74	75	76	77	78	79	79	80	81	82	83	84	84	85	86	87
32	75	75	76	77	78	79	80	81	82	83	83	84	85	86	87	88	89
33	76	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	90
34	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
35	77	78	79	81	82	83	84	85	86	87	88	89	90	91	92	93	94
36	78	79	81	82	83	84	85	86	87	88	89	90	91	92	94	95	96
37	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	96	97
38	80	81	83	84	85	86	87	89	90	91	92	93	94	96	97	98	99
39	81	82	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101
40	82	83	85	86	87	89	90	91	92	94	95	96	98	99	100	101	103

Note. Green – comfort zone; yellow – a little stress; orange – moderate stress; brown – strong stress; violet – very strong (hard) stress.

By the method of simple linear regression, it is established that when the temperature rises by one degree Celsius, the relative humidity of the air will decrease by approximately two percent (R^2 = 0.36). At the same time, the range of fluctuations in relative humidity of the air at the same temperature values was quite large (Figure 4) and depended on changeable weather conditions.

According to the data (Table 4), animals can be exposed to low heat stress even at a temperature of 20°C, moderately at 23°C, and are in a state of severe heat stress at 30°C (including taking account the type of uninsulated cowsheds). The likelihood of severe stress in dairy cows is extremely low, but it is theoretically possible at air temperatures above 32°C.

Thus, the calculated values of temperatures and relative humidity in the rooms, obtained by constructing linear regression models, make it possible to predict the values of THI in uninsulated cowsheds. They can be used

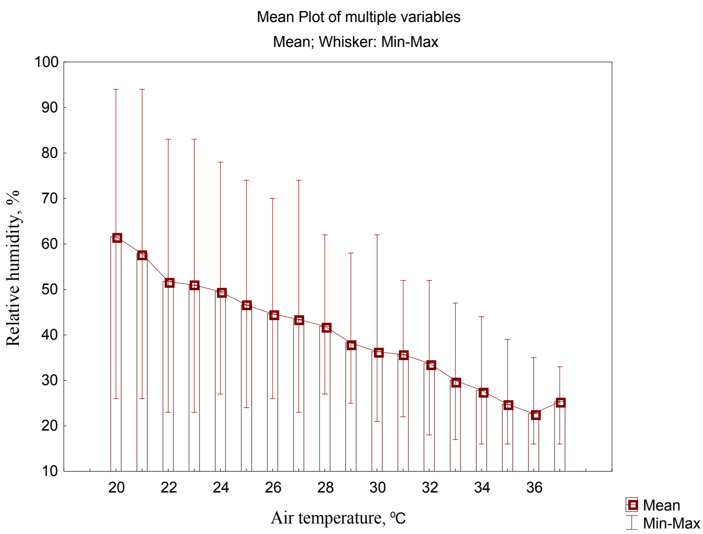

Figure 4. Dynamics of temperature and humidity of the air at the location of the dairy complex in the hot season

as a reference when choosing the type of room for keeping dairy cows and assessing the state of their comfort, given the climatic features of the temperate continental climate of the Steppe of Ukraine.

5. Conclusion

Repeated measurement of temperature and humidity of air inside and outside the premises for animals allows predicting the state of the microclimate by building mathematical models. It has been established that the temperature and humidity conditions in an uninsulated cowsheds are directly determined by the state of the environment, and also depend on the design features of the room. The temperature-humidity index is a convenient integral indicator of the climate in the cowsheds. It allows you to evaluate the comfort of dairy cows in conditions of high temperatures. The THI prediction for an individual dairy complex, taking into account its geographical and climatic location, will make timely management decisions to normalize the climate in an uninsulated cowshed.

References:

1. Anderson, N.G. (1997). Cold housing and open housing – effects on health, management and production dairy cattle. Proceedings of the 9th International Congress in Animal Hygiene, 17–21 August 1997, Helsinki, Finland. Pp. 481–487.

2. Angrecka, S. & Herbut, P. (2016). Conditions for cold stress development in dairy cattle kept in free stall barn during severe frosts. Czech Journal of Animal Science, 60 (No. 2), 81–87. doi: 10.17221/7978-cjas

3. Bohmanova, J., Misztal, I. & Cole, J. B. (2007). Temperature-Humidity Indices as Indicators of Milk Production Losses due to Heat Stress. Journal of Dairy Science, 90(4), 1947-1956. doi: 10.3168/jds.2006-513.

4. Bravo, D. M. & Wall, E. H. (2016). The rumen and beyond: Nutritional physiology of the modern dairy cow 1. Journal of Dairy Science, 99(6), 4939–4940. doi: 10.3168/jds.2015-10191.

5. Buryakov N. P., Buryakova M. A., Aleshin D. E. (2016). Teplovoy stress i osobennosti kormleniya molochnogo skota [Heat Stress and Heat Stress and Feeding Features of the Dairy Cattle]. Rossiyskiy veterinarnyiy jurnal, 3, 5-13. (in Russian)

6. Carabaño, M. J., Logar, B., Bormann, J., Minet, J., Vanrobays, M.-L., Díaz, C., … Hammami, H. (2016). Modeling heat stress under different environmental conditions. Journal of Dairy Science, 99(5), 3798–3814. doi: 10.3168/jds.2015-10212/

7. Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati & Kumar, R. (2016). Impact of heat stress on health and performance of dairy animals: A review. Veterinary World, 9(3), 260–268. doi: 10.14202/vetworld.2016.260-268

8. Fan, C., Su, D., Tian, H., Li, X., Li, Y., Ran, L., … Cheng, J. (2018). Liver metabolic perturbations of heat-stressed lactating dairy cows. Asian-Australasian Journal of Animal Sciences, 31(8), 1244–1251. doi: 10.5713/ajas.17.0576

9. Fiedler, M., Hoffmann, G., von Bobrutzki, K., Matzarakis, A. (2010). Biometeorological investigations in dairy cowsheds. In: Matzarakis, A., Mayer, F. & Chmielewski, M. (Eds.) Proceedings of the 7th Conference in Biometeorology. BIOMET 12 -14 April 2010, Freiburg, Germany.

10. Fodor, N., Foskolos, A., Topp, C. F. E., Moorby, J. M., Pásztor, L. & Foyer, C. H. (2018). Spatially explicit estimation of heat stress-related impacts of climate change on the milk production of dairy cows in the United Kingdom. PLOS ONE, 13(5), e0197076. doi: 10.1371/journal.pone.0197076

11. Fournel, S., Ouellet, V., & Charbonneau, É. (2017). Practices for Alleviating Heat Stress of Dairy Cows in Humid Continental Climates: A Literature Review. Animals, 7(12), 37. doi: 10.3390/ani7050037.

12. Gantner, V., Bobic, T., Gantner, R., Gregic, M., Kuterovac, K., Novakovic, J. & Potocnik, K. (2017). Differences in response to heat stress due to production level and breed of dairy cows. International Journal of Biometeorology, 61(9), 1675–1685. doi: 10.1007/s00484-017-1348-7

13. Hodanovich B. (2012). «Holodnyie» korovniki: uroki surovoy zimyi i jarkogo leta [«Cold» cowsheds: lessons from the harsh winter and hot summer]. Jivotnovodstvo Rossii. Spetsvyipusk, 25-28. (in Russian)

14. Kibler, H.H. (1964). Environmental physiology and shelter engineering. LXVII. Thermal effects of various temperature-humidity combinations on Holstein

cattle as measured by eight physiological responses. Res. Bull. Missouri Agric. Exp. Station. 862.

15. Lambertz, C., Sanker, C. & Gauly, M. (2014). Climatic effects on milk production traits and somatic cell score in lactating Holstein-Friesian cows in different housing systems. Journal of Dairy Science, 97(1), 319–329. doi: 10.3168/jds.2013-7217/

16. Liu, Z., Ezernieks, V., Wang, J., Arachchillage, N. W., Garner, J. B., Wales, W. J., … Rochfort, S. (2017). Heat Stress in Dairy Cattle Alters Lipid Composition of Milk. Scientific Reports, 7(1). doi: 10.1038/s41598-017-01120-9

17. Malinin I. (2017). Teplovoy stress: novyie faktyi [Heat stress: new evidence]. Jivotnovodstvo Rossii, 6, 26-28. (in Russian)

18. Malinin, I. & Sadovnikova, N. (2016). Teplovoy stress: pravila igryi [Heat stress: rules of the game]. Jivotnovodstvo Rossii, S3, 32–35. (in Russian)

19. Malinin, I. & Sadovnikova, N. (2016). Vliyanie teplovogo stressa na produktivnost molochnogo i myasnogo skota [Effect of heat stress on the productivity of dairy and beef cattle]. Effektivnoe jivotnovodstvo, 5(126), 34–37. (in Russian)

20. McDonald J. H. 2009. Handbook of Biological Statistics. Sparky House Publishing, Baltimore.

21. Molodkovets, O., Zakharenko, M. (2016). Microclimate livestock buildings and premises for loose–boxed maintenance, forsed and voluntary milking cows. Scientific Messenger LNUVMBT named after S.Z. Gzhytskyj, 18, 4(72), 41–46. (in Ukrainian)

22. Overton, M. W., Sischo, W. M., Temple, G. D. & Moore, D. A. (2002). Using Time-Lapse Video Photography to Assess Dairy Cattle Lying Behavior in a Free-Stall Barn. Journal of Dairy Science, 85(9), 2407–2413. doi: 10.3168/jds.s0022-0302(02)74323-3

23. Piron O. & Malinin I. (2015). Nujno li predotvraschat teplovoy stress u doynyih korov? [Is it necessary to prevent heat stress in dairy cows?]. Effektivnoe jivotnovodstvo, 3-4(113), 18-20. (in Russian)

24. Schüller, L. K. & Heuwieser, W. (2016). Measurement of heat stress conditions at cow level and comparison to climate conditions at stationary locations inside a dairy barn. Journal of Dairy Research, 83(03), 305–311. doi: 10.1017/s0022029916000388

25. Sejian, V., Pragna, P., Archana, P. R., Aleena, J., Krishnan, G., Bagath, M., Manimaran, A., Beena, V., Kurien, E. K., Varma, G. & Bhatta, R. (2017). Heat Stress and Dairy Cow: Impact on Both Milk Yield and Composition. International Journal of Dairy Science, 12(1), 1–11. doi: 10.3923/ijds.2017.1.11

26. Skibiel, A. L., Zachut, M., do Amaral, B. C., Levin, Y. & Dahl, G. E. (2018). Liver proteomic analysis of postpartum Holstein cows exposed to heat stress or cooling conditions during the dry period. Journal of Dairy Science, 101(1), 705–716. doi: 10.3168/jds.2017-13258

27. Tao, S., Orellana, R. M., Weng, X., Marins, T. N., Dahl, G. E. & Bernard, J. K. (2018). Symposium review: The influences of heat stress on bovine mammary gland function. Journal of Dairy Science. doi: 10.3168/jds.2017-13727

28. Vaculíková, M., Komzáková, I. & Chládek, G. (2017). The Effect of Low Air Temperature on Behaviour and Milk Production in Holstein Dairy Cows.

Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 65(5), 1623–1627. doi:10.11118/actaun201765051623

29. Vasilenko T., Milostiviy R., Kalinichenko A., Milostiva D. (2018). Heat stress in dairy cows in the central part of Ukraine and its economic consequences. Social and economic aspects of sustainable development of regions: monograph, 128–135.

30. Vasilenko, T., Milostiviy, R. & Kalinichenko, O. (2018). Influence of high temperature on dairy productivity of Ukrainian Schwyz. Relevant Issues of Development and Modernization of the Modern Science: The Experience of Countries of Eastern Europe and Prospects of Ukraine. doi: 10.30525/978-9934-571-26-8_3

31. Vasilenko, T. O., Milostiviy, R. V., Kalinichenko, O. O., Gutsulyak, G. S. & Sazykina, E. M. (2018). Influence of high temperature on dairy productivity of Ukrainian Schwyz. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies, 20(83), 97–101. doi: 10.15421/nvlvet8319

32. Voloshchuk, V. M. & Khotsenko A. V. (2017). Dynamika temperatury povitria ta vnutrishnikh elementiv konstruktsii korivnyka karkasnoho typu za dii faktoriv zovnishnoho seredovyshcha [Dynamics of air temperature and internal structural elements of the barn frame type on effects of environmental factors]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia : Tvarynnytstvo, 5(2), 37–41. (in Ukrainian)

33. Vysokos, M.P., Milostiviy, R.V., Typina, N.V. & Kalinichenko, A.O. (2015). Zoogigijenichna ocinka umov utrymannja molochnogo gurtu golshtyns'koi' hudoby za parametramy mikroklimatu monobloku korivnyka v regioni Prydniprov'ja [Hygienic assessing conditions of Holstein dairy cattle in microclimate parameters monoblock cowshed in the region Pridneprovya]. Naukovo-tehnichnyj bjuleten' NDC biobezpeky ta ekologichnogo kontrolju resursiv APK, 3(4), 74–78. (in Ukrainian)

34. Wang, X., Gao, H., Gebremedhin, K. G., Bjerg, B. S., Van Os, J., Tucker, C. B. & Zhang, G. (2018). A predictive model of equivalent temperature index for dairy cattle (ETIC). Journal of Thermal Biology, 76, 165–170. doi:10.1016/j.jtherbio.2018.07.013

35. Zakharenko, M., Voloshchuk, V. & Khotsenko, A. (2018). Produktyvnist koriv zarubizhnoi selektsii za bezpryviazno-boksovoho utrymannia ta dii vysokoi temperatury povitria [The productivity of cows of foreign breeding is impaired-boxing and exposure to high air temperature]. Naukovyi visnyk NUBiP Ukrainy. Seriia: Tekhnolohiia vyrobnytstva i pererobky produktsii tvarynnytstva, 271, 225–234. (in Ukrainian)