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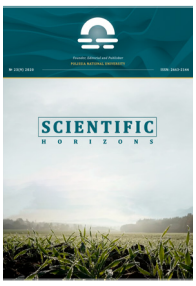

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Behavior and Energy Losses of Cows during the Period of Low Temperatures

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Abstract. Over the past 20 years, dairy farms in Ukraine have been actively introducing the keeping of cows in easy-to-assemble premises. However, in a moderate climate (with four distinct year seasons), the issues of microclimate, energy losses of animals and their behavior during the cold period of the year for keeping in such premises have not been fully studied. The purpose of this work was to study the influence of the heat insulation elements use of side curtains in easy-to-assemble premises during the period of low temperatures on microclimate, energy outgoings for thermoregulation and behavior of cows. The research conducted in the central part of Ukraine (Kyiv region). The research was conducted during January-February (29-43 days of the year) 2021. This period characterized by low average daily temperatures of -12.2 – -18.7°C, strong wind gusts and daily precipitation in the form of snow. Two easy-to-assemble premises for 400 heads were used for research. Parameters of placements (LxWxH): 150x32x10.5 m. The first one was without the use of curtains heat insulation elements, and the second one was with these elements of heat insulation. It was found that the use of polycarbonate wall heat insulation elements had a positive effect on the microclimate in the placement during the period of low temperatures. Indicators of average daily air temperatures in the placement were 3.2 and 8.8°C higher compared to the temperature in the same premise without the use of heat insulation elements and the environment. The wind speed also differed by 0.18 and 11.04 m/s, respectively. In addition, the heat insulation of the walls affected the temperature under the lying cow (+1.8°C), energy outgoings for thermoregulation (-1.93 MJ) and the number of cows that lay in the period of the lowest temperatures (+3.23-9.83%) compared to the placement without heat insulation elements. The difference in temperature of rubber carpet in the compared premises was significant: +3.3°C in the premises with heat insulation elements compared to the premises without heat insulation

Keywords: dairy, cold stress, easy-to-assemble premises, Wind-Cold index, Cold-Stress index

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INTRODUCTION

The efficiency of milk production largely depends on how to use animals properly, taking into account their biological characteristics, including behavior. Behavior is one of the most important indicators of detecting any abnormalities in animal health and productivity. It appears in all elements of production technology, forming in combination with climatic (weather, microclimate), planning (premises, stalls, playgrounds), technical (mechanisms and equipment) and organizational (daily routine) complex system "organism-environment" [1].

Ethological and physiological studies of the effects of weather phenomena occupy an important place in the development of effective methods in agricultural production. In the system of interaction "organism-environment" such environmental factors as climate and weather become important. Influencing agricultural production, they determine the efficiency of livestock and crop production. Ethological researches are necessary, first of all, for creation of optimal housing conditions, both at industrial complexes and at traditional farms. Dealing with the current intensity of dairy farming, weather and climatic conditions are an important component of the proper organization of cattle keeping and livestock farms' infrastructure and require some understanding of the mechanisms of meteorological conditions influence on animals and the ability to manage these mechanisms in practical animal husbandry. The study of behavioral reactions of animals of different breeds makes it possible to find ways to increase their productivity under specific conditions of feeding and keeping [2].

It is known that changes under external conditions lead to a restructuring of the adaptive behavior of animals, their motor activity. In a certain environment, the behavior of animals remains constant only when their daily routine is not limited and has no additional loads. The animal and the environment in which it lives form an integral unit. Each change in environmental conditions causes some disturbance in the vital balance of animals, forcing them to adapt to these changes. The ability of cows to resist these changes depends on species, breed, age and technological differences [3].

Adaptation of livestock breeds to local climatic conditions is an important feature of modern agriculture, as it helps to reduce the impact of temperature stress to which animals are exposed, and leads to increased livestock production. Under the influence of evolutionary factors, cattle underwent a long natural selection and adapted to various environmental conditions from Africa and equatorial America to central and northern Siberia. Domestication has resulted in more than 1.000 existing breeds with varying levels of productivity, product quality, feed conversion and other economically important characteristics [4].

Thermoregulatory mechanisms allow animals to adapt to different temperature fluctuations and tolerate significant deviations in air temperature. However, at violation of the heat balance in cows, resistance and productivity are reduced and there are significant changes in behavioral responses compared to the normal state. Functional abnormalities in the body of domestic animals are possible due to too high and too low air temperatures. Prolonged exposure to high or low temperatures increases (or decreases) heart rate and respiration, activates sweat glands, evaporation, reduces mobility, appetite, feed conversion, feed nutrient intake, productivity and rest duration [5].

Warming of light-ventilation curtains in winter is of great importance when keeping cows in easily assembled premises in countries with a temperate-continental climate, including Ukraine. It has been established that the use of insulation of curtains with the use of polyvinyl chloride can prolong for 13 days the permissible norms of wind speed indoors and more effectively protect animals from the environment at different categories of wind speed, as well as reduce indoor air speed by 11.68-21.74% compared to uninsulated rooms of different configurations and heights of longitudinal walls [6].

The purpose of this work was to study the effect of heat insulation elements use of side curtains made of polycarbonate material in easy-to-assemble barn during the period of low temperatures on indicators of microclimate, resting place temperature, energy outgoings for thermoregulation and behavior of cows.

LITERATURE REVIEW

The influence of weather factors on the welfare and productivity of cows has been studied in the vast majority in terms of high temperatures [7]. The influence of cold on the body mostly been studied in beef cattle or dairy cattle under conditions of year-round grazing [8]. However, in recent decades, due to global climate change trends in Central and Eastern Europe there have been increasing winter temperature fluctuations that have had a negative impact on the welfare of dairy cows [9]. These processes cause great losses to agricultural producers due to reduced productivity and irrational use of feed resources [10].

The value of ambient temperature has a fundamental influence on the functioning of dairy cattle [11]. S. Angrecka found that thermo-neutral for the body of dairy cattle is the temperature in the range from -5 to 25°C [12]. J. West states that a change in temperature in the range from -0.5 to +25°C does not affect the productivity of cows [13]. Most breeds are quite sensitive to higher and lower temperatures in this range. A. Yáñez-Pizaña in his research indicates that dairy cattle and Water Buffalo are able to produce milk at temperatures up to -30°C under conditions of limiting the effects of wind and precipitation [14]. A. Yurchenko report that Yakut cattle found above the Arctic Circle and are able

to adapt to too low temperatures (up to -50°C) [4]. Under conditions of thermo-neutral temperature, the body spends minimum amount of energy to maintain life or balance with the environment. Nonetheless, the amount of heat lost is equal to the amount of produced heat. In the measure of moving away from the optimum temperature in the direction of its reduction, energy exchange and the level of heat production increases, which leads to irrational feed costs and a corresponding decrease in feed conversion [15-17]. Cold weather affects the physiological characteristics and behavior of cattle [1]. The sympathetic nervous system causes three main physiological responses to cold stress: increased heat production metabolism, increased heart rate, and mobilization of free fatty acids for metabolism [18]. Behavioral responses to low temperatures can be divided into two categories: the animal's search for a warm, comfortable place to rest to reduce the effect of temperature and change the duration of basic behaviors [19].

F. Duranovich report about the negative effects of prolonged cold load on cows' bodies. Studies in New Zealand under pasture conditions indicate significant changes in behavior and productivity during the low temperature period [20]. The duration of lying and grazing in cows decreased compared to the thermo-neutral period. One of the solutions to this issue, along with genetic and feeding factors, are the factors of modernization of the premises, which would take into account the peculiarities of seasonal sharp changes in the main weather indicators [21]. Such factors include the installation of fans and irrigation systems, installation of canopies on feedlots in summer and heat insulation of premises in winter [12; 22].

MATERIALS AND METHODS

Climate and Barns

The research was conducted in the central part of Ukraine (Kyiv region 49 °51′27′′ North latitude, 30 °6′36′′ East longitude). Two easy-to-assemble barns with a loose housing of 400 cows were used for the research. Parameters of placements (LxWxH): 150x32x10.5 m. The first one was without use of heat elements of curtains, and the second analogous one was with heat elements of longitudinal walls by polycarbonate glass (Fig. 1). One section of polycarbonate glass (Carboglass, Ukraine) has parameters: 5x1.85x0.01 m. Sections of polycarbonate mounted to internal parties of vertical metal designs for the period of low temperatures (November-March) in the plane of lateral curtains. The transparency of polycarbonate glass is 86%. The material has high thermal heat insulation, sound heat insulation (17 dB) and impact resistance (900 kJ/m^2) properties.

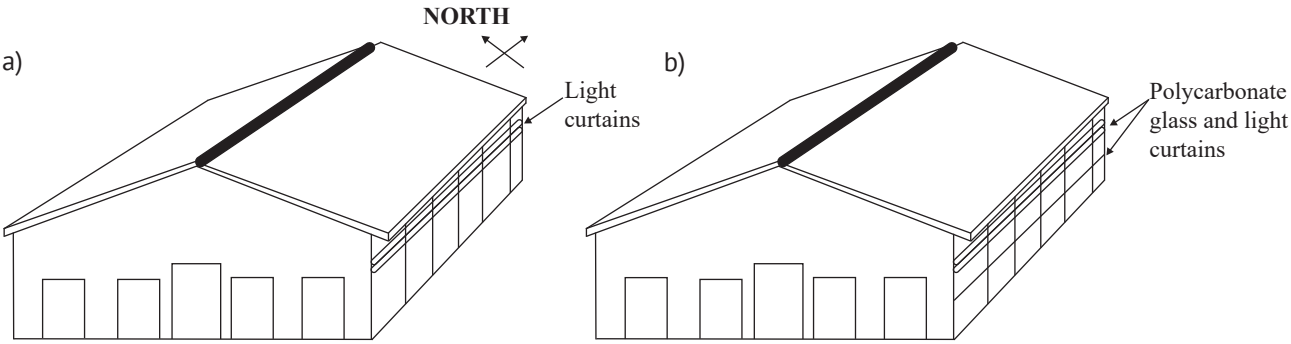

Figure 1. *Easy-to-assemble premises without (a) and with (b) elements of heat insulation*

The research was conducted during January-February (29-43 days of the year) 2021. This period characterized by low average daily temperatures of -12.2–-18.7°C, strong wind gusts and daily precipitation in the form of snow. The duration of daylight during the experimental period ranged from 9 hours 11 minutes to 9 hours 57 minutes.

Measurement Methodology

The average daily air temperature, relative humidity, wind speed and precipitation were determined according to the Kyiv Center for Hydrometeorology. The temperature and relative humidity were measured by VOLTCRAFT DL-141 sensor (Germany) with a measuring range for temperatures from -40 to +70°C and relative humidity from 0 to 100%. The sensors were placed in the zone occupied by cows 0.5 m above the floor. All the measurement results were recorded automatically every 10 min. The wind speed inside the barn was determined by wind speed and direction sensor TFA WeatherHub (TFA, China). The cows skin surface temperature was determined in two places: on rumen and in the region of the last inter costal space by using a remote infrared thermometer Thermo Spot-Plus (Germany). The temperature at the resting place as well as under the lying cow was determined by the thermometer A36PF-D43 (USA). Costs of energy for heat production were calculated according to the methods of C.T. Kadzere [23]. Cow' behavior was determined by using indoor security cameras. 8 Hikvision cameras (Full HD) were installed in both barns. With an interval of 2 hours recorded the number of cows that lie, stand, consume feed and drink water. Recreation areas in both rooms were equipped with rubber carpets produced by Kraiburg (Germany). Daily application of cereal straw is 2.0 kg per 1 head.

Animals

Holstein cattle cows (93-118 days of lactation) used to study the main behavioral indicators. The location of the sections in which the cows were housed in both buildings was similar. In the room without the use of heat insulation elements, the number of groups was n=88, and in the room with heat insulation elements made of polycarbonate glass n=85.

Calculation of and wind chill temperature index and cold stress index

The wind chill temperature index (WCT) was calculated according to C. Tucker [24]. This index helps to evaluate the effect of low air temperature in combination with the wind speed on the cold stress of animals:

$$WCT=13.12+0.6215\cdot T_{air}\cdot 13.17\cdot V^{0.16}+0.3965\cdot T_{air}\cdot V^{0.16} \quad (1)$$

where: WCT – wind chill temperature, °C; T_{air} – air temperature, °C; V – wind speed, km h^{-1}.

The cold-stress index (CSI), which indicates the level of animals stress resistance to sharp wind speed and precipitation, was determined by the J.R. Donnelly method [25]:

$$CSI=[11.7+(3.1\cdot WS\ 0.5)]\cdot(40-T)+481+R \quad (2)$$

where: CSI – cold-stress index, $MJ/m^2/h$; WS – mean daily wind speed, m s^{-1}; T – is the mean daily temperature, °C.

$$R = 418\cdot(1-e^{-0.04\cdot rain}) \quad (3)$$

where: $rain$ is the total daily rainfall in millimeters; e – natural logarithm = 2.718.

Statistical Analysis

The obtained data were statistically processed using STATISTICA (Version 11.0, 2012) software. The Student's *t*-test was used to estimate the statistical significance of the obtained values. Data were considered significant at P<0.05, P<0.01, P<0.001.

RESULTS AND DISCUSSION

The results of research showed the influence of the use of polycarbonate heat insulation elements on the average daily values of air temperature, relative humidity and wind speed in the premise (Table 1). These figures per 3.2°C; 0.2% and 0.18 m/s were dominated the similar results obtained in the placement without the use of heat insulation elements. Comparing the indicators of the microclimate in the rooms with environmental weather conditions, the largest difference found in terms of wind speed. In the rooms without the use of heat insulation elements, the difference was – 10.86 m/s, while in the premises with the use of heat insulation elements – 11.04 m/s compared to the average environmental temperature. Indicators of air temperature in the studied premises were respectively higher by: 5.6 and 8.8°C compared to ambient temperature. Regarding the relative humidity, the difference with the environmental indicator constituted 8.4% in the rooms without heat insulation elements, and in the insulated premise 8.6%.

Table 1. *Indicators of air temperature, relative humidity and wind speed of the environment and premises*

Indicators	Environment			Easy-to-assemble premises			Easy-to-assemble premises with elements of heat insulation		
	Mean±	Min	Max	Mean±	Min	Max	Mean±	Min	Max
	SEM			SEM			SEM		
Temperature, °C	-15.9±0.17	-12.2	-18.7	-10.3±0.08†††	-5.9	-12.7	-7.1±0.06$^{\dagger\dagger\dagger;***}$	-4.8	-9.8
Relative humidity, %	94.3±5.56	88.1	98.0	85.9±2.19	77.6	90.8	85.7±2.74	79.5	92.7
Speed of wind movement, m/sec	11.6±0.27	7.3	15.8	0.74±0.05†††	0.62	0.85	0.56±0.03$^{\dagger\dagger\dagger;**}$	0.48	0.64

Note: *SEM: standard error of mean; †††P<0.001 as compared with environment; **P<0.01; ***P<0.001 as compared with easy-to-assemble premises*

The results of research coincide with the data obtained in the studies of S. Angrecka conducted in Poland, which showed a significant temperature decrease in the premise of the easy-to-assemble type during prolonged negative temperatures during winter [26]. F.K. Teye in their studies conducted in Estonia and Finland indicate a decrease in daily air temperature in barns to -20°C and below during periods when the ambient temperature was below -30°C [27]. A group of researchers obtained similar research results from China Z. Cao, who indicate a decrease in air temperature in easy-to-assemble premise (from -0.97 to 8.10°C) during the period when the ambient temperature was -20°C and below [28].

Among the weather factors that affect the comfort and well-being of cows during the year is wind speed. In winter, at negative temperatures, gusts of wind can lower the temperature of air masses, which in turn affects the productivity, energy outgoings for thermoregulation and animal behavior. Research coincides with data obtained by P. Herbut, which indicates an increase in wind

speed in rooms with side curtains during periods of low temperatures [29].

The greatest influence on the duration of animals rest, along with the nature of the kennel (hard or elastic coating, the presence or absence of litter, clean or dirty, dry or wet) and the type of litter, the heat capacity of litter material has. When the animal is lying down, ⅓ part of the surface of its body is in contact with the floor, so the kennel should be warm enough. Heat losses through the floor are 12-20% of the total heat losses of the room and depend on the thermo-physical characteristics of the floor and bedding material. The temperature indicators of rubber carpets did not differ from the average daily temperature in the premises (Table 2). Thus, in the premises without heat insulation elements the difference was +0.1°C, and in the premises with heat insulation elements: +0.2°C. The temperature difference of the carpets between the actual premises was significant: +3.3°C in the premises with heat insulation elements compared to a room without heat insulation. Body and skin temperature of dairy cows vary depending on weather conditions, microclimate parameters, as well as options for keeping animals and the type of litter material. In research, the influence of heat insulation elements on the skin temperature during low temperatures has been established. In the room with the use of heat insulation elements, the value of this indicator was 0.4°C higher compared to the control premise.

***Table 2**. Indicators of temperature of places of rest, skin of animals and energy outgoings for heat production*

Indicators	Easy-to-assemble premises			Easy-to-assemble premises with elements of heat insulation		
	Mean±SEM	Min	Max	Mean±SEM	Min	Max
Temperature of rubber carpet, °C	-10.2±0.08	-5.6	-12.3	-6.9±0.06***	-4.4	-9.5
Temperature of animal's skin, °C	28.8±0.11	28.2	29.3	30.2±0.14***	29.5	30.8
Temperature under the lying cow, °C	20.3±0.09	18.9	21.6	22.1±0.12***	21.6	22.8
Energy for heat production, MJ	54.37±0.79	54.71	54.03	52.44±0.53*	52.61	52.32
Wind-Cold index, °C	-13.41±0.34	-16.11	-10.02	-9.14±0.21***	11.39	6.85
Cold-Stress index, MJ/m²/h	1517.14±25.41	1502.56	1535.08	1454.83±12.98*	1436.77	1471.54

***Note**: *P<0.05; ***P<0.001 as compared with easy-to-assemble premises*

Heat losses through the floor are 12-20% of the total heat losses of the room and depend on the thermo-physical characteristics of the floor and bedding material. It is quite irrational for an animal to lose the energy of fodder for the creation and use of thermal energy, for heating the kennel, instead of converting it into milk. At low temperatures, cows increase the outgoings of physiological heat. When these outgoings exceed 100 kcal/h (0.418 MJ/h), then during 12 hours (average duration of rest of the cow in the supine position) they are equivalent per caloric content of 2 kg of milk. The value of the temperature under the lying cow in the cold period quantitatively demonstrates the energy outgoings intended for thermoregulatory processes for heating the rest area. The difference between the premises with heat insulation and without it constituted +1.8°C.

Prolonged low average daily temperature causes an increase of energy outgoings for heat production. Energy outgoings for evaporation, radiation and convection directly related to ambient temperature and have a significant impact on the behavior and productivity of cows. It was found that in the room with heat insulation elements; the average daily outgoings of exchange energy for heat production was 1.93 MJ lower than in the room without heat insulation.

Indicators of wind-cold (WCT) and cold-stress (CSI) indices assessed the effects of low temperatures in combination with air velocity and precipitation on cold stress. The value of WCT evaluates the effect of low temperatures combined with the speed of indoor air movement on productivity, comfort and housing behavior of cows. It was found that in the premise with heat insulation elements, the average WCT value was 4.27°C higher than in the premises without heat insulation elements. Knowledge of CSI allows you to consider how wind speed and quantity of weather elements, which are the main factors in the perception of objective temperature, influence on the productivity and behavior of cows. In premise with heat insulation elements, the CSI value was 80.37 MJ/m²/h lower than in the premise without the

use of heat insulation elements. The dependence of indoor air temperature and basic behavior indicators has been established (Table 3). Thus, during the period of maximum low-temperature load from 00.00 to 06.00, the vast majority of animals in both rooms rested lying down. In the premise without heat insulation elements (temperature range from -11.7 to -12.4°C), the number of cows that rested during this period ranged from 56.81% to 78.40%. Whereas in the premise with heat insulation elements (temperature range from -8.5 to -9.8°C), this value constituted from 60.04% to 88.23%. It is believed that for maximum milk production in two hours after the distribution of feed cows should rest in lying position. In studies, the number of cows resting in lying position at 10.00 am and 20.00 pm in the premise with heat insulation was 15 and 4 heads higher than in the premise without elements of heat insulation.

***Table 3**. Monitoring of ethological indicators during the period of low temperatures*

Hours	Easy-to-assemble premises (n=88)				Easy-to-assemble premises with elements of heat insulation (n=85)			
	Air temperature, °C	Lay	Stand	Consume feed and drink water	Air temperature, °C	Lay	Stand	Consume feed and drink water
00.00	-11.7	69	11	8	-8.5	75	6	4
02.00	-12.3	57	26	5	-9.2	60	19	6
04.00	-12.7	50	22	16	-9.8	51	8	26
06.00#	-12.4	–	–	–	-9.5	–	–	–
08.00‡	-11.2	6	17	65	-8.9	4	12	69
10.00	-9.5	22	20	46	-7,1	37	9	39
12.00	-6.2	41	14	33	-6.0	44	5	36
14.00	-5.9	43	17	28	-4.8	44	11	30
16.00#	-7.1	–	–	–	-5.3	–	–	–
18.00‡	-8.4	4	23	61	-6.1	3	15	67
20.00	-10.2	39	15	34	-7.0	43	6	36
22.00	-10.8	51	8	29	-7.9	57	3	25

***Note**: # – periods of cows' milking; ‡ – time of forage distribution*

Rest of cows in the lying position together with feed consumption is the main ethological indicators, the value of which indicates both positive and negative signs of housing technologies. Data do not coincide with the data of C. Muller [30] and A.D. Fisher [31], who report that at low temperatures the duration of lying cows decreased. The results of study coincide with the data of D.C. Adams, who found that at low temperatures, both feed activity and the duration of food intake decrease slightly [32]. However, M. Vaculikova in their studies conducted in the Czech Republic report about increase in the number of cows lying in periods of lower temperatures [33]. D. Lovarelli in the study conducted in northern Italy (Lombardy) also indicate an increase in the duration of rest in lying position in cows during periods of low temperatures (2.56-10.14°C) compared to the thermo-neutral period [34].

CONCLUSIONS

The use of polycarbonate wall heat insulation elements had a positive effect on the microclimate in the premises during the period of low temperatures. The average daily air temperature in the room was 3.2 and 8.8°C higher compared to the temperature in the similar room without the use of heat insulation elements and the environment. The wind speed during the period of low temperatures was lower by 0.18 and 11.04 m/s, respectively, in comparison with the values of the environment and premises without heat insulation elements. Heat insulation of the walls influenced on the temperature under the lying cow (+1.8°C), energy outgoings for thermoregulation (-1.93 MJ) and the number of cows that lay in the period of the lowest temperatures (+3.23-9.83%) compared to the barn without heat insulation elements. It was found that in the premise with heat insulation elements, the average WCT value was 4.27°C higher than in the premises without heat insulation elements. In premise with heat insulation elements, the CSI value was 80.37 MJ/m^2/h lower than in the premise without the use of heat insulation elements.

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Поведінка та енергетичні втрати у корів упродовж періоду низьких температур

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Анотація. У тваринництві України за останні 20 років активно впроваджуються легкозбірні приміщення для утримання молочної худоби. Проте в умовах помірного клімату (з чотирма чітко вираженими сезонами року) питання мікроклімату, витрат енергії тваринами та їхньої поведінки упродовж холодного періоду року за утримання у таких приміщеннях повністю не вивчені. Метою цієї роботи було вивчити вплив використання елементів утеплення бокових штор у легкозбірному корівнику протягом періоду низьких температур на показники мікроклімату, витрат енергії на терморегуляцію та поведінку корів. Дослідження проводили у центральній частині України (Київська область) протягом січня-лютого (29–43 дні року) 2021 року. Цей період характеризувався низькими середньодобовими температурами -12,2 – -18,7 °С сильними поривами вітру та щоденними опадами у вигляді снігу. Для досліджень використовували два легкозбірних корівника на 400 голів. Параметри приміщень (ДхШхВ): 150х32х10,5 м. Перший без використанням елементів утеплення штор, а другий аналогічний з елементами утеплення. Встановлено, що використання елементів утеплення стін із полікарбонату позитивно вплинуло на показники мікроклімату у приміщенні протягом періоду низьких температур. Показники середньодобової температури повітря у приміщенні були на 3,2 та 8,8 °С вищими порівняно з температурою в аналогічному приміщенні без використання елементів утеплення та навколишнього середовища. Швидкість руху вітра також відрізнялась на 0,18 та 11,04 м/с відповідно. До того ж утеплення стін вплинуло на показник температури під лежачою коровою (+1,8 °С), витрати енергії на терморегуляцію (-1,93 МДж) та кількість корів, котрі лежали у період максимально низьких температур (+3,23-9,83 %) порівняно з приміщенням без елементів утеплення. При цьому показники температури матраців були вищими від середньої добової температури навколишнього середовища лише на 0,1 °С у приміщеннях без утеплення, а у приміщеннях з елементами утеплення на 0,2 °С. Різниця температури матраців між приміщеннями була суттєвою: +3,3 °С у приміщенні з елементами утеплення порівняно з приміщенням без утеплення

Ключові слова: молочна худоба, холодовий стрес, легкозбірні приміщення, вітро-холодовий індекс, холодо-стресовий індекс