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EFFECT OF THREE BEDDING MATERIALS ON THE MICROCLIMATE CONDITIONS, COWS BEHAVIOR AND MILK YIELD

Alexandr A. Borshch[1], ***Sergey Ruban***[2], ***Alexandr V. Borshch***[1], ***Olena Babenko***[1]

[1] Chair of Technology of Milk and Meat Production
Bila Tserkva National Agrarian University in Bila Tserkva, Ukraine
[2] Chair of Genetics, Breeding and Reproductive Biotechnology
National University of Life and Environmental Science of Ukraine in Kyiv, Ukraine

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Abstract

This work aim was to study the influence of low temperatures on the behavior, productivity and heat production of cows with different types of bedding material (deep litter, sawdust, compost manure) keeping conditions. During keeping at low temperatures on deep litter, the highest average daily temperature was observed (-11.8°C) and the lowest humidity was 84.4% as compared to the sawdust and compost manure litter. There were observed higher temperature values of the room and resting place under the lying cow when keeping on a deep litter. The total energy expenditure for heat production in cows with keeping on deep litter was by 2.95 and 2.43 MJ lower, as compared to keeping on sawdust and compost manure bedding. With temperature decrease there was observed a tendency to increase the duration of rest in a lying position with all variants of litter. The highest value was with keeping on deep litter – 846 minutes per day. At the same time, the duration of food consumption was slightly decreased. Productivity of cows, when keeping on sawdust litter, declined by 9.11% (2.38 kg), with compost manure bedding – by 8.36% (2.45 kg), and with deep litter – by 5.31% (1.36 kg).

Introduction

Among weather factors, affecting the functioning of dairy cattle, the most impact is done by environment temperature (GANTNER et al. 2011, SCHÜLLER et al. 2014). KNIZKOVA et al. (2002) have found out that thermo--neutral temperature for dairy cattle is in the range from -5 to 25°C. WEST (2003) states that the temperature change in the range from -0.5 to + 25°C

Address: Alexandr A. Borshch, Bila Tserkva National Agrarian University, pl. 8/1 Soborna 09100, Bila Tserkva, Ukraine, phone: +38 098 622 07 97, e-mail: borshcha@outlook.com

does not affect the cows productivity. During thermo-neutral temperature, the body spends a minimum amount of energy to maintain life or balance with the environment. The amount of lost heat is equal to the amount of produced heat. As the distance from the optimal temperature goes higher or lower, the energy exchange and the level of heat production increases, which leads to inappropriate consumption of feed and relevant reduction in feed conversion. The effect of cold on the body was mostly investigated on meat or lactating animals in conditions of year-round grazing (GRANKE et al. 2011, WEBSTER et al. 2008). However, the low temperature has a negative effect on the cows body also when kept inside (HERBUT 2013, BORSHCH et al. 2017a). Cold weather has an impact on the cattle physiological characteristics and behavior (BERGEN et al. 2001, KENNEDY et al. 2005). The sympathetic nervous system causes three basic physiological responses to cold stress: increase in heat production metabolism, pulse rate, and mobilization of free fatty acids for metabolism (BROUCEK et al. 1991). Behavioral reactions to low temperature can be divided into two categories: search for a warm comfort rest place to reduce the temperature factor influence and change in the duration of the basic behavior acts (HOUSEAL and OLSON 1995, REDBO et al. 2001). When cows are kept inside at low temperatures, the lying position rest and food eating duration increases (FISHER et al. 2003). Cold stress significantly affects animals body during keeping the whole year on pastures. Thus, the research results of TUCKER et al. (2007) and WEBSTER et al. (2008), conducted in New Zealand under grazing conditions, indicate significant changes in behavior and productivity during a periodof cold load. Lying and grazing duration decreased in comparison with the thermo-neutral period. Low temperature, combined with wind and precipitation, increases the cortisol level in cows blood, which is a stress marker (WEBSTER et al. 2008). Animals begin to seek shelter in the form of a tree, or sheds, and are reluctant to lie on wet and dirty land, which leads to loss of productivity (SCHUTZ et al. 2010). Accordingly, the effect of these conditions leads to the cows increased metabolic activity to provide heat to maintain their body temperature (AMES 1987). As a result, there is an increased need for energy for the basic metabolism (main exchange), and accordingly the amount of energy for other processes, such as milk production and sexual activity, decreases (BROUCEK et al. 1991).

The bedding material has special place in ensuring comfort of dairy cows (VAN GASTELEN et al. 2011, MITEV et al. 2012, BORSHCH et al. 2017b, JONES et al. 2017). The most common litter material in Ukraine is the straw of grain crops. In addition, depending on the geological and industrial characteristics of certain regions, sand, sawdust, peat and compost manure are also used. Each of these litter variants has advantages and

disadvantages, connected with storing, depositing, removing, recycling and ensuring the closest natural conditions for comfort and well-being of cows at high and low temperatures (HULSEN 2006, ECKELKAMP et al. 2016, PILATTI and VIEIRA 2017).

Our research purpose was to study the influence of different bedding material types during the cold-thermal period on the behavior, productivity and heat production of cows.

Material and Methods

Climate

The research was conducted at various temperature periods in the central part of Ukraine (49°34'56" North latitude, 30°38'10"East longitude; 49°48'45" North latitude, 30°38'56' East longitude; 48°57'47" North latitude, 30°7'57" East longitude) during January 2018. The first period (12 days) was thermo-neutral with average daily temperature + 2.8°C, and the second cold-thermal period (10 days) with temperature -17.9°C with strong wind and daily precipitation in the form of snow. The main weather indicators in different periods of research are given in the Table 1. The Ukraine territory is located in a moderate belt. The continental climate is characterized by four distinct seasons of the year. The winter weather changes average daily temperature from +4 to -18°C. This range is due to frequent changes in air mass types. Tropical air masses provide warm and dry weather in winter, and the arctic ones – long low temperatures, sometimes with significant precipitation in the form of snow.

Table 1

The main weather indicators in different periods of research

Indicators	Thermo-neutral period	Cold-thermal period
Air temperature [°C]	2.8	-17.9
Relative air humidity [%]	54.8	94.3
Wind speed [km h^{-1}]	18.4	59.8
Average daily precipitation amount [mm]	28	429

Stall bedding types and barns

To conduct our research, there were selected three farms with cows, kept on different types of bedding material: deep straw litter, sawdust and compost manure. All the farms had lightweight types talls and each of

barns are divided into 4 sections. In a deep litter stall there were kept 409 cows. The room parameters were (L x W x H): 100 x 60 x10.5 m. Animals rest in a separated zone from the feeding passage. The straw delivery into recreation area is done daily at 8 kg rate per head. Manure removal is performed three times a year. A stall with sawdust litter holds 422 cows. Room parameters are: 150 x 40 x 10 m. Animals rest in boxes equipped with rubber mattresses. The stall with compost manure litter holds 393 cows. Parameters of the room are 150 x 40 x 10.5 m. The solid manure fraction is disinfected and dried in an aerobic bioreactor for 24 hours (dry matter content 36–41%). Rest of cows takes place in the boxes. Compost manure brought into the boxes everyday (layer 2–3 sm). Removal of manure from passages is carried out by a scraper. The farms apply same type year-round feeding of cows with complete mixed fodders. The feeding level is quite high: animals consume 21.5–22.4 kg of dry matter per day, the energy value of the consumed feed is 211–223 MJ.

Animals

The Holstein breed cows were used as the research material. The dynamics of productivity, dry matter consumption and behavior in different temperature periods were studied on all the livestock. Energy expenditure for heat production was studied in cows after 60–70 days of lactation (n = 25).

Behaviour

Cow's behavior was determined using internal surveillance cameras. In farm with deep straw litter installed 12 IP cameras (2 MP). In farms with sawdust and compost manure litters installed 16 Hikvision cameras (Full HD). Filming in all barns takes place around the clock. Placing cameras in the barns allows you to record a recreation area, feeding passage and drinking bowls area and also cows moving. At first processed obtained data for each of the four sections. After it determined average indicators on a farm. The daily behavior of cows was studied during 2 consecutive days in the thermo-neutral period and in the period of low temperature. Every 10 minutes, in experimental groups, there was recorded the number of cows, which during the observation consumed food, were resting by standing or lying, were moving and drinking water. Data undertook by us from video cameras two last days before temperature decrease and two first days after temperature decrease.

Thermal conditions

The air temperature and relative humidity in the barns were determined by a combined digital environment meter Velleman, model DVM401 (Belgium). The wind speed inside the barn was determined by handheld pocket digital anemometer AZ, model AZ-8919 (Taiwan). The average daily precipitation was determined by the Kyiv Center for Hydrometeorology. 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 KADZERE et al. (2002).

Calculation of and wind chill temperature index and cold stress index

The wind chill temperature index (WCT) was calculated according to TUCKER et al. (2007). This index helps to evaluate the effect of low air temperature in combination with the wind speed on the cold stress of animals:

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

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 DONNELLY (1984) method:

$$CSI = [11.7 + (3.1 \cdot WS^{0.5})] \cdot (40\text{-}T) + 481 + R$$

where:

CSI – cold-stress index [$MJ/m^2/h$]

WS – mean daily wind speed [m s^{-1}]

T – is the mean daily temperature [°C]

$$R = 418 \cdot (1\text{-}e^{-0,04 \cdot rain})$$

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 cattle organism is under the constant influence of combined action of meteorological factors: temperature, humidity, atmospheric pressure, air speed, precipitation. At the same time, one of them may be overwhelming, and other factors increase or weaken its effect on the organism of animals. The manifestation of meteorological phenomena within a day can widely vary and affect their health, behavior and productivity (BROUCEK et al. 1991, KADZERE et al. 2002, ANGRECKA and HERBUT 2015).

The results of our research indicate that the decrease in air temperature in combination with wind gusts and atmospheric precipitation significantly influenced the indoor microclimate (Table 2). Due to daily straw and excrement accumulation and the permanent microbiological processes in the bedding, the room air temperature with the deep litter was somewhat higher than when using of other types of bedding material (SOMMER 2001).

Table 2

Indoor microclimate indicators under different weather conditions

Indicators	Thermo-neutral period			Cold-thermal period		
	deep litter	sawdust	compost manure	deep litter	sawdust	compost manure
Air temperature [°C]	6.7±0.22	5.7±0.31*	6.4±0.38	-11.8±0.14	-14.4±0.29***	-13.9±0.16***
Relative air humidity [%]	55.3±2.56	56.3±3.32	56.9±1.71	84.4±2.37	85.7±2.74	85.9±2.19
Wind speed [km h^{-1}]	1.58±0.05	1.72±0.08	1.65±0.04	2.66±0.11	2.66±0.18	2.62±0.12

Note: as compared with deep litter bedding material *$P < 0.05$; ***$P < 0.001$.

Thus the average daily temperature during keeping on deep litter decreased by 18.5°C, as compared with the thermos-neutral period, and amounted –11.8°C. The most significant decline was observed in the keeping technology with sawdust as litter material – by 19.9°C, with an average temperature of -14.4°C, which is by 1.5 and 2.6°C lower than when keeping on compost manure and deep litter. Indoor keeping of cows on all types of litter material, had the air humidity increase during the period of temperature load by 29.1–29.5%. The highest average daily air humidity was in rooms with compost manure bedding – 85.9%. With the deep litter and sawdust technology, these values were 84.4% and 85.7% respectively. This is explained by the fact that the daily adding of straw, which has a hygroscopic quality of 450%, contributes to a decrease in the room humidity.

Sawdust as bedding material has also high hygroscopic quality – 490% (NORRING et al. 2008). In addition, wind speed also increased during the cold thermal period by 0.94 to 1.08 km/h in comparison of thermos-neutral period.

By the wind chill temperature (WCT) and cold-stress (CSI) indices there was estimated the influence of low temperatures in combination with air flow speed and precipitation on the cold stress. In the cold period, with all variants of litter, there was observed WCT and CSI decrease (Table 3).

Table 3

The indoor bio-climatic indices values in temperature load period

Indicators	Bedding material		
	deep litter	sawdust	compost manure
Wind-Cold index [°C]	-17.06±0.27	-18.72±0.26***	-18.17±0.31***
Cold-stress index [MJ/m^2/h]	1671.46±73.74	1713.88±81.42	1700.51±67.87

Note: as compared with deep litter bedding material ***$P < 0.001$.

The WCT value shows the effect of low temperatures, combined with the air flow speed in the room, on productivity, comfort of keeping conditions and behavior of cows. According to our research, it was found that the lowest average daily value of WCT in the period of low-temperature load was in the keeping technology, using sawdust as a litter -18.72°C. At the same time in a room with compost manure litter this value was somewhat higher and amounted -18.17°C. The highest value was observed in keeping animals on deep litter – (-17.06°C).

Knowledge of CSI allows to consider how wind speed and precipitation, which are the main factors of the real temperature sensing, affect the productivity and behavior of cows. The highest average daily value of CSI was observed with keeping on the sawdust litter – 1713.88 MJ/m^2/h. With keeping on compost manure and deep straw bedding, these indicators were somewhat lower – 1700.51 and 1671.46 MJ/m^2/h, respectively.

The environmental temperature is the biggest influence on the thermal state of animals, changing the course of vital processes. The thermoregulatory mechanisms allow animals to adapt to different temperature fluctuations of the environment and to transiently tolerate significant temperature deviations from the usual for them values. However, the body heat regulation values are not limitless and the violation of the thermal equilibrium changes the physiological state, resistance to diseases and animal productivity. Functional body disorders are possible due to the action of both very high and very low air temperature. High productivity is closely linked to high heat production (BERMAN et al. 1985). In the indu-

strial conditions, dairy cows experience lack of heat in the winter and transition seasons of the year. Decrease of the indoor air temperature dramatically increases the body heat release (LOBECK et al. 2011, ITO et al. 2014). Animals are trying to reduce the heat release, thus the pulse slows down, breathing deepens, and food consumption increases. Due to excessive and prolonged air temperature decrease the animals over cooling occurs, and this helps to provoke chills and other diseases. Daily yield at average daily temperature below -10°C can be reduced by 12–14%, and at temperatures below -20°C the loss of productivity is even greater.

The greatest impact on the duration of animal rest, along with the bed characteristics (solid or elastic coating, the presence or absence of litter, clean or contaminated, dry or wet) and the type of litter, has the heat capacity of the bedding material (CALAMARI et al. 2009, ECKELKAMP et al. 2014). When the animal is lying, one third of its body surface contacts the floor, so the floor should be quite warm. Loss of heat through the floor is 12–20% of the total heat loss of the room and depends on the floor thermo--physical characteristics and the bedding material. Feed energy loss by animal for creation and use of heat energy, to warm the bed, instead of turning it into milk is rather irrational. Low temperature cause the increase of physiological heat expenditures in cows. When these costs exceed 100 kcal h^{-1}, then for 12 hours (average rest period in a lying position), they are equivalent to a caloric value of 2 kg of milk (KIBLER and BRODY 1951).

In our studies, the resting places temperature was not much different from the indoor air temperature (Table 4). The highest temperature of resting places during the cold period for cows on deep litter was – (-11.4°C), which is by 2.1 and 1.9°C higher than for keeping on the sawdust and compost manure bedding. The temperature of the resting place under the lying

Table 4

Temperature indices of rest places and energy expenditure for heat production in different weather conditions (n = 25)

Indicators	Thermo-neutral period			Cold-thermal period		
	deep litter	sawdust	compost manure	deep litter	sawdust	compost manure
Rest place temperature [°C]	5,8±0,15	5,1±0,20**	5.3±0.12*	-11.4±0.39	-13.5±0.84*	-13.3±0.57**
Rest place temperature under lying cow [°C]	26.5±0.42	23.8±0.78**	24.2±0.58**	24.5±1.03	19.9±1.17**	20.5±1.24*
∑ energy for heat production [MJ]	45.34±1.03	45.73±1.12	45.59±1.38	54.08±0.88	57.03±1.23*	56.51±1.39

Note: as compared with deep litter bedding material *$P < 0.05$; **$P < 0.01$

cow during the cold period was also the highest in deep litter – 24.5°C, which is by 4.0 and 4.6°C higher than for keeping on the compost manure and sawdust bedding.

Significant decrease in the average daily temperature for all keeping options led to increase in energy expenditure on heat production. The energy expended on evaporation, radiation and convection is directly related to the ambient temperature and has a significant impact on the cows behavior and productivity. In experimental cows with keeping on deep litter the energy consumption for heat production was increased by 8.74 MJ, as compared with the thermo-neutral period. The heat production on the compost manure and sawdust bedding increased by 10.78 and 11.44 MJ, respectively. The highest average daily energy expenditure was observed with keeping on sawdust bedding – 57.03 MJ. This is explained by the fact that, along with good hygroscopic and adsorption properties of sawdust at low temperatures, it is less heat accumulating in comparison with other variants of the bedding material.

A similar tendency was observed for all types of bedding material in the cold period: the duration of rest in the lying position increased by 47–53 min in comparison with the thermo-neutral period (Table 5).

Table 5

Duration of main daily behavior reactions under different weather conditions, min (n = 25)

Indicators	Thermo-neutral period			Cold-thermal period		
	deep litter	sawdust	compost manure	deep litter	sawdust	compost manure
Lying	793±8.93	761±8.72*	774±10.63	846±6.11	808±12.94*	821±8.24*
Fodder consuming	274±3.91	259±2.63**	286±3.35*	265±4.19	252±5.32**	274±3.53*
Moving	56±0.16	48±0.21***	58±0.27***	39±0.12	32±0.19***	42±0.26***
Standing	181±2.24	212±3.49***	162±2.57***	174±3.51	187±2.26***	159±3.18***
Water drinking	39±0.21	31±0.54***	36±0.17***	25±0.14	27±0.32***	32±0.22***

Note: as compared with deep litter bedding material $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$

At the same time, the increase in the duration of rest in the lying position was accompanied by a reduction of time for walking, standing and water drinking. Duration of feed consumption during the low temperature period has somewhat decreased. Our data do not coincide with the data of MULLER et al. (1996) and FISHER et al. (2003) who report, that at low temperatures the lying time of cows has decreased. The results of our studies coincide with the data of ADAMS et al. (1986), which show that at low tempera-

tures there is some reduce in feed activity and duration of eating. The cows rest in lying position together with the feed consumption are the main ethological indicators, which values indicate both positive and negative signs of keeping technologies and use of different bedding material types. The highest duration of cows resting during the cold period was with keeping on deep litter – 846 minutes, which is by 23 and 38 min more than for keeping on compost manure and sawdust, respectively. Under keeping with the optimal daily delivery of straw, which is extremely effective heat--insulating material, and it also massages and dries the animal's skin, provides the most comfortable conditions (LOMBARD et al. 2010).

Our studies do not coincide completely with the studies of OFNER--SCHRÖCK et al. (2015), which found that in the thermo-neutral period with keeping cows on the compost manure bedding, the duration of rest in a lying position was prevailing similar indicators for other types of bedding material.

Typically, low temperature periods are accompanied by cow productivity decrease by 5–20% (KADZERE et al. 2002). It is established that at low temperatures the feed conversion is reduced. Our studies confirm this evidence, because in all variants of litter material in experimental cows there was a decrease in productivity (Table 6).

Table 6

Cow productivity and feed conversion under different weather conditions

Indicators	Thermo-neutral period			Cold-thermal period		
	deep litter	sawdust	compost manure	deep litter	sawdust	compost manure
Yield [kg]	25.63±0.51	26.12±0.84	27.34±0.46	24.27±0.73	23.74±1.08	24.89±0.32
Dry matter consumption [kg]	21.43±0.23	21.77±0.36	22.43±0.31**	21.38±0.25	21.63±0.38	22.36±0.43*
Feed conversion, kg of dry matter [kg of milk]	1.19	1.20	1.22	1.13	1.08	1.11

Note: as compared with deep litter bedding material *$P < 0.05$; **$P < 0.01$

Thus, the greatest reduction in cow productivity was under the technology of keeping with on sawdust litter – by 9.11% or 2.38 kg. The keeping on compost manure litter during the cold period, the average decline in productivity was 8.96% or 2.45 kg. At the same time, the highest productivity stability during low-temperature load was showed by the cows keeping technology on deep litter. Under this variant of the litter, the productivity dropped only by 5.31% or 1.36 kg. As for the dry matter consumption during the cold period there was no significant decrease of this indicator

for different variants of the litter material – by 0.05–0.14 kg. This is due to the fact that low temperatures led to decrease in the duration of feed consumption by cows. Decrease in productivity and consumption of dry matter, along with an increase in the cost of heat production, resulted in feed conversion decrease by 0.06 kg of dry matter kg^{-1} of milk with keeping on deep litter and by 0.11 and 0.12 kg of dry matter kg^{-1} of milk with keeping on compost manure and sawdust.

Conclusions

The air temperature decrease became a significant stress factor, which significantly influenced the duration of basic behavioral reactions and productivity of cows, as compared to the thermo-neutral period. The keeping technology on deep straw bedding due to the higher thermal insulation and hygroscopic properties and constant microbiological processes in it showed the best indicators of microclimate. At the same time, due to a smaller decrease of the indoors air temperature, there were the smallest losses of energy for heat production and productivity decrease of cows, as compared to keeping on sawdust and compost manure litter.

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