Scientific Papers. Series D. Animal Science. Vol. LXIII, No. 1, 2020
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

A STUDY OF THE FARM FACTORS IN BUILDINGS USED FOR FARMING DAIRY COWS

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Abstract

A study of the farm factors was conducted in three buildings used for farming dairy cows. They were kept free in individual boxes or as a group living on deep litter bedding. Two of them were open and the third was closed structure. The average monthly and seasonal values of temperature, humidity and air movement were calculated. It was found that temperature, humidity and air movement in the buildings depend on the season, type of building and environmental factors. The daily thermo-hygrograms made during typical summer and winter days show the actual state of the farm factors in the buildings. The topographical distribution of floor temperatures in open buildings, compared to closed ones, confirmed their higher degree of dependence on ambient temperatures. The results were statistically processed using IBM, SPSS-21.

Key words*: farm factors, floor temperature, thermo graphic profile.*

INTRODUCTION

The formation of optimal microclimate in the building used for breeding dairy cows is of essential importance for the maintenance of sustainable health status and realisation of maximum productivity (Gauly et al., 2013). The diversity of buildings with different technical and technological solutions used in the cattle breeding is often a hindrance for the establishment and keeping up of an optimal temperature-humidity and light regime in them. The microclimate which is specific for each production building not only influences the food assimilation (Gaughan et al., 2002; Mader and Davis, 2004), the health and productivity of the cows (Solan and Jozwik, 2009; Darwin, 2001), their comfort (Heidenreich et al., 2004; Broucek et al., 2009; Velecka et al., 2014; Trofimov et al., 2016), but also their reproduction (Ravagnolo and Mistzfal, 2002). The temperature, humidity and air currents are leading in this respect (Gregoriadesova and Dolezal, 2000). In their publication, Ventura et al. (2015) examine the “cows comfort” as a combination of the environmental factors, design and construction characteristics of the building and their technological equipment which all lead to a certain behavioural reactions of the animals. When it comes to the influence of the light on the metabolism, reproduction, health and milk productivity of the cows, Trofimov et al. (2016) believe that the studies are still insufficient. A regular control and assessment of the barn environment will provide the opportunity for timely correction and forecasting of the health and productivity of the cows in the long run.

The maintenance of the microclimate in the being now constructed semi-open buildings without longitudinal side walls is regulated by curtain walls which open and close depending on the air flow. Using the behavioural indicators, Dinev (2007) ascertains that these building can ensure suitable temperature, humidity and air flow speed in compliance with the physiological needs of the cows.

The task we set to ourselves was to examine the variable factors of the production environment in three buildings used for breeding dairy cows during transitional, summer and winter periods.

MATERIALS AND METHODS

The studies were carried out in the course of one year in three cattle breeding farms with different capacity in the region of Plovdiv. The breeding technology in two of them is free in individual boxes, and as a group living on deep litter bedding in the third one. We nominated the farms provisionally with numbers (№ 1, 2 and 3) in view of keeping their confidentiality.

Farm № 1 has a capacity of 500 lactating cows kept free in separate boxes. 200 lactating cows divided into 4 groups are bred in the controlled building. Its total area is 2310 m², and the individual space per animal 11.5 m². The building is a concrete construction with concrete walls and roof panels.

The individual boxes are set on both sides of the longitudinal walls and have dimensions of 1.10/2.10 m. between them and the feeding zones are the manure alleys. The floor of the building and the individual boxes is made of cement, and that in the boxes is covered with a soft rubber bedding. There are no partition systems or chest restrain belts in the front. The feeding is via cattle feed mechanical mixer in the morning and in the evening.

The natural light in the barn is ensured by a total of 30 windows with an area of 220.5 m² and 12 ridge vents with an area of 62.5 m². The artificial lighting is fluorescent and is performed via 97 double-tube fluorescent lamps 40 W each. The side windows and the ridge vents are covered with a polyethylene sails during the winter. The mechanical ventilation is performed via 10 ventilators - 5 on both sides of the feeding lanes, above the movement and feeding zone; each ventilator has a power of 0.55 kW and productivity of 60,000 l/h.

The manure is cleaned with a delta scraper every 3 hours. The watering is performed with 16 nipple drinking troughs divided into 4 per each group of 50 animals. The milking is twice a day in a cow milking parlours type «Fish-bone» 2 x 8.

Farm № 2 has a capacity of 250 dairy cows bred freely in separate boxes. The controlled building accommodates 130 dairy cows divided into two groups of 65 cows each. It is an open metal construction with a thermopanel roof. The side walls are made of concrete with width of 0.25 m and height of 1.5 m. The end walls are also made of concrete and are 3.0 m high. The feeding lane zone has no doors and is entirely open. The total area of the building is 1248 m² and each animal has 9.4 m² individual area ensured.

The feeding lane is centrally positioned. On both of its sides are mounted rows of two-sided individual boxes (1.25/2.20) which are separated by manure lanes at the side walls and the feeding lanes. The floor is made of cement and that in the boxes is covered with a rubber bedding.

The natural light is ensured by the open spaces with a total area of 170 m². The artificial light is provided by 14 three-tube fluorescent lamps 40 W each. The mechanical ventilation is performed by 8 ventilators placed under angle of 45º (4 on both sides of the feeding lane), above the feeding zones. Each of the ventilators has a wattage of 0.55 kW and productivity of 60,000 l/h. When the temperature is up to 18ºC only half of them work, and when it is above 25ºC- all do.

The cleaning of manure is made with a delta scraper every 6 hours. The feeding is unlimited with a total mixed ration with a permanent access to water. Milking is performed twice a day in milking parlours 2 x 12 type «Fish-bone» equipped with a herd management software product.

Farm № 3 has a capacity of 110 cows bred free in a group living on deep litter bedding. The building controlled is for 67 dairy cows and has a total area of 598.5 m². The movement and rest area are 540 m². Each cow is ensured 8.06 m². The building is semi-opened, the roofs are made of double bricks without inner or outside coating. The feeding lane is situated in the east side of the rest and movement area. The open parts of the building provide natural ventilation close to the tunnel type. In addition, 8 ventilators (DeLaval) are mounted under 45º above the rest and movement area, each with a wattage of 0.55 kW and productivity of 60,000 l/h. The same are turned on in stages in temperatures above 18 and 25ºC.

The feeding is unlimited with a total mixed ration and a permanent access to water.

The cleaning of manure is made twice a year with periodic addition of hay. The milking is performed twice a day in a milking parlours «DeLaval» 2 x 5. Apart from the natural lighting there are also 5100 W lamps fixed above the feeding lane and 3200 W lamps - above the rest and movement area.

All microclimatic factors both outside and inside the buildings were measured at 10, 12, 14, 16 and 18 h in the course of three days every month. The temperature of the floor and the air outside and inside the premises was measured with a multifunction thermometer. Compact infrared thermometer 105,518 with a scope from -50 to +550ºC and resolution of 0.1ºC, we measured the relative humidity (%) through an aspiration psychrometer by Assmann, the air flow speed (m/s) with a catathermometer, the atmospheric pressure (hPa) with an aneroid barometer type 103, Germany, and the illumination - with a lux meter PU 150 PRAHA. The ammonia concentration was ascertained with detector tubes manufactured by the company "Hygitest" Bulgaria. In the course of 3 to 5 days during each of the controlled months, we registered the daily fluctuations in the air temperature and the relative humidity with the help of weekly thermo hygrographs. The results were statistically processed via IBM, SPSS-21.

RESULTS AND DISCUSSIONS

To a large extent, the optimal microclimate or its maintenance within tolerable norms depends on whether the requirements for: stocking density, the volume available per animal, feeding and watering front are met (Dimova et al., 2012; Dinev, 2007). Our results indicated that each dairy cow is ensured 11.5 m², 9.4 m², 8.06 m² instead of the 6 m² required under Ordinance 44 (2006) and the Technological requirements for building of livestock and poultry farms and complexes (1982).

The farms subject to our studies are situated in the Upper Thracian Plain which is characterized by a transcontinental climate. Table № 1 clearly shows that the registered average daily temperatures, humidity and air flow in the region of each of the farms are approximately the same.

With minor exceptions, the region of farm № 3 is a bit hotter during the summer and cooler during the winter. The differences, however, are statistically unsubstantiated.

Table 2 features the average values of the examined parameters with no view of the farm and the season. It can be seen that the outdoor temperatures vary between 3 and 26.8ºC, and the inside ones - between 5.2 and 28.8ºC. The relative humidity values in the premises are mainly within the hygiene norms.

Table 1. Average temperature-humidity regime values in the region of the examined farms

Parameters	Transitional period			Summer			Winter		
	Building 1	Building 2	Building 3	Building 1	Building 2	Building 3	Building 1	Building 2	Building 3
Temperature, ºC	19.3	19.6	20	28.8	27.5	28.5	3	3.2	3.6
Relative humidity, %	70.6	69.1	68.5	58.2	55.4	59.2	55.2	67.4	68.5
Air flow speed, m/s	0.28	0.26	0.25	0.21	0.25	0.24	0.61	0.72	0.68

Table 2. Average values of the examined parameters with reference to the three seasons

Parameters	№	LSM	±SE	SD	Minimum	Maximum
T 1, ºC	54	16.29	1.25	9.21	3.0	26.8
T 2, ºC	54	18.94	1.22	8.98	5.2	28.8
T 3, ºC	54	15.10	1.16	8.50	2.2	25.9
H 1, %	54	68.31	0.73	5.33	58.2	75.2
H 2, %	54	74.44	0.90	6.61	65	88
AM, m/s	54	0.35	0.025	0.18	0.15	0.66

Note: T 1 - outside temperature; T 2 - inside temperature; T 3 - floor temperature; H 1 - relative humidity of the outside air; H 2 - relative humidity of the inside air; AM - movement of air in the buildings.

According to Petkov and Baikov (1976), natural factors such as temperature, humidity, air flow, which characterize the atmosphere and topography total circulation, are also major components acting upon formation of the microclimatic parameters of the closed (№

1) and the two open (№ 2 and 3) dairy cows production buildings (Table 2) studied by us.
The suitable temperature and relative humidity in the production premises guarantee the cosiness and the comfort of the animals bred there. They are also a prerequisite for good health condition and maximum productivity of the animals (Gaughan et al., 2000; Miteva, 2012; Hansen, 2007). According to Regulation 44, the temperature comfort zone of dairy cows is between 10 and 15ºC, at a minimum of 5ºC and a maximum 28ºC. Hanus et al. (2008) state that the thermal neutral zone of the dairy cows is between 3 and 13ºC because phylogenetically, cows fall in the group of the arctic animals.
As presented in Table 3, the average values of the examined hygiene parameters in the controlled buildings demonstrate their own dynamics with reference to each building but at the same time some dependence on the factors of the outside environment. When a comparison is made with the values recommended in Regulation № 44 it can be seen that in the winter, the cows from these farms live in an environment with temperatures below the lower limit (5ºC) and during the summer - in close or exceeding the upper limit (28ºC).

Table 3. Average values of the microclimate factors in the controlled buildings

	Transitional period			Summer			Winter		
Parameters	Building 1	Building 2	Building 3	Building 1	Building 2	Building 3	Building 1	Building 2	Building 3
Temperature, ºC	22	21.8	22.5	28.2	27.8	27.6	7.1	5.8	6.9
Relative humidity, %	73	68	70	79.0	64.8	75	85	73	76
Air flow speed, m/s	0.28	0.22	0.36	0.56	0.49	0.55	1.2	1.5	0.9
Cooling variable, mJ/cm²/s	9.5	8.8	10.2	4.5	3.1	4.8	9.5	13.8	7.8
Illumination, Lx:	400-600	350-750	200-450	400-1200	400-700	250-700	250-550	220-700	180-450
Ammonia content, mg/l	14.4	8	15.2	0.25	0,22	0.28	0.21	0.18	0.24
Bedding temperature, ºC	18.5	16.2	12.5	25.9	25,7	22.6	9.8	6.3	2.5

The data in Table 4 show the high correlation dependency of the air and floor temperature, and the air flow on the architecture-constructional and technological solutions in the production buildings. The relative humidity has a negative correlation not only with the type of building but also with the temperature maintained in it. The season of examination also highly affects the temperature of the air and the floor, and the air flow in the production buildings but not the humidity inside them.
The use of the average temperature and humidity values which are usually measured during the daytime (7, 14 and 21 h) does not provide precise but general idea about the temperature-humidity regime in the buildings. The amplitudes and their duration usually are not revealed. Namely these features are of extreme importance upon unlocking of a certain stress reaction.

Table 4. Correlation between the examined parameters and reliability degree

	T 2, ºC	T 3, ºC	H 2, %	AM, m/s
Season	0.97***	0.91***	-0.1	0.90***
Farm	0.99***	0.93***	-0.47***	0.8***

Note: ***P<0.001; **P<0.01; *P<0.05
T 2 - indoor temperature; T 3 - floor temperature; H 2 - indoor air relative; AM - air flow in the buildings

The thermo-hygrograph diagrams (Figures 1, 2, 3, and 4) made by us provide a more precise idea about the real condition of these ecological factors during typically hot and typically cold days of the year.
The thermo-hygrograph diagrams show that in farm № 1, the temperatures during the summer vary from 20 to 40ºC, and the amplitudes sometimes exceed 20ºC. The relative humidity at the same time varies between 30 and 90%. In the winter, the amplitudes both of the temperature and the relative humidity are

almost two times lower. The registered winter temperatures in the premises of farm № 1 are always above 0ºC.

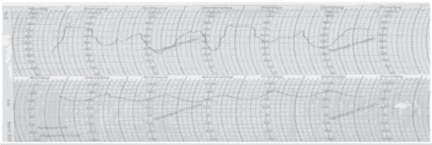

Figure 1. Thermo-hygrograph diagram from farm № 1 taken in the summer

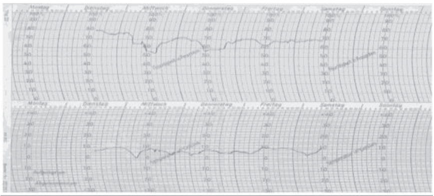

Figure 2. Thermo-hygrograph diagram from farm № 1 taken in the winter

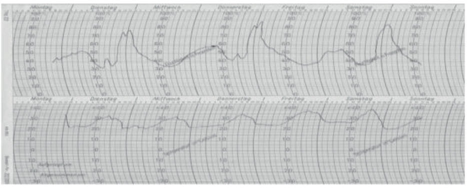

Figure 3. Thermo-hygrograph diagram from farm № 2 taken in the summer

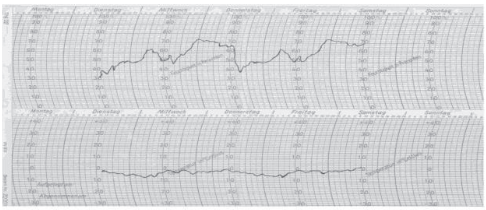

Figure 4. Thermo-hygrograph diagram from farm № 2 taken in the winter

It can be observed that during the summer the temperature and relative humidity fluctuations in the premises of the three farms are within close values. The thermo-hygrograph diagrams taken in the open buildings during the winter indicate fewer variations or entirely overlap with those of the outside temperature. This comes to prove that to a large extent, the temperature- humidity regime in them is more dependent on the atmospheric factors than the closed building is.

It is well known that the dairy cows are more tolerant to low than high temperatures. However, the continuous effect of the low temperatures may prove to be stressful. Nardone et al. (2006) observe reduction in the milk productivity at temperatures of minus 4ºC. They point the temperature of minus 23ºC as a critical lower level. Bianka (cited by Petkov and Baikov, 1976) considers that the dairy cows can also be bred in conditions close to 0ºC. It is also added that provided the feeding is good, the low temperatures increase the resilience of the animals, while the high temperatures have a negative effect on them.

To what extent the temperature and humidity in the buildings may be considered corresponding to the physiological needs of the animals also depends on the airflow and its cooling ability. The results of our studies indicate that the air flow and the cooling variable during the summer are quite low in all three farms - from 0.49 to 0.56 m/s and from 3.1 to 4.8 mcal/cm²/s. In the winter the air flow speed in two of the farms exceed the accepted norm 4 times. When this speed is maintained for a longer period of time, especially in temperatures under 0ºC, we can say that a cold stress prerequisite arises. Under the norms, acquired in our country, the air flow speed during the winter must not exceed 0.3 m/s, and the cooling variable- 5-8 mcal/cm²/s. Even at temperatures under 10ºC, no flows should be allowed. In their overview material, Petkov and Baikov (1976) cite authors according to whom the air flow must not exceed 0.6 m/s, and that it could exceed even 4 m/s according to others. Therefore, we reasonably support the conclusion of Gregoriadesova and Dolezal (2000) stating that the cows' welfare, their health and productivity during the summer are mainly affected by the temperature and humidity of the air, and during the winter - by its speed.

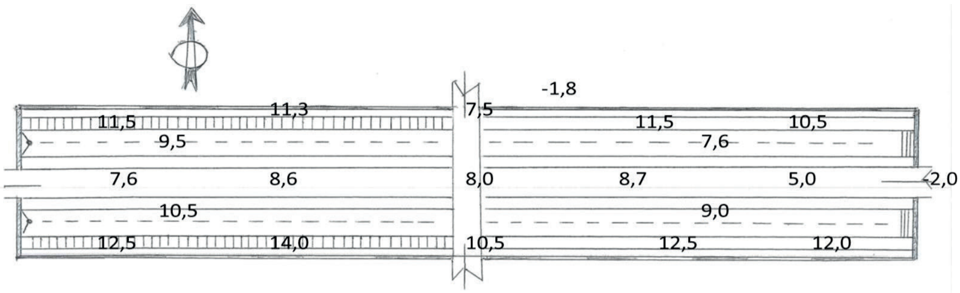

Figure 5. Topography of the floor temperatures in building № 1 during the winter

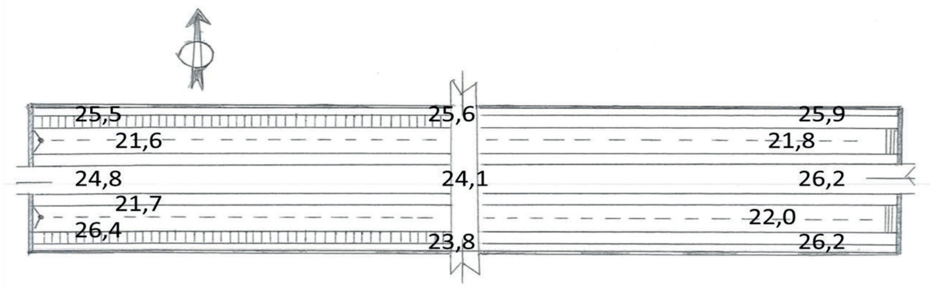

Figure 6. Topography of the floor temperatures of building № 1 during the summer at an outside temperature of 35ºC

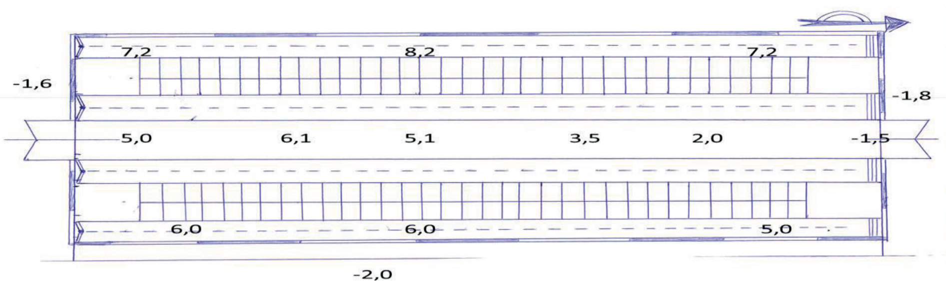

Figure 7. Topography of the floor temperatures in building №2 during the winter

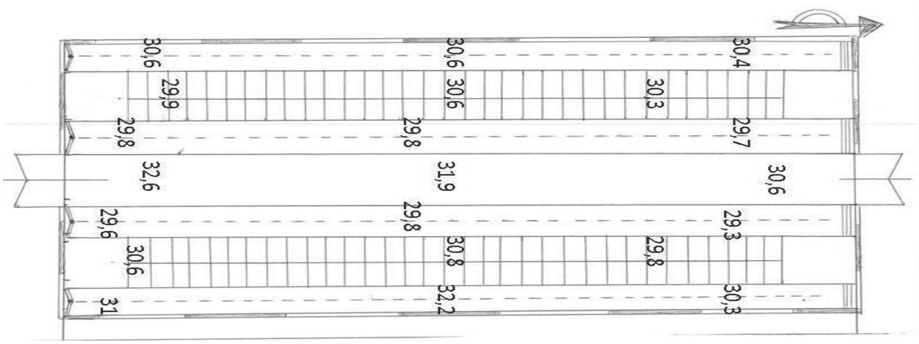

Figure 8. Topography of the floor temperatures in building № 2 at an outdoor temperature of 35ºC

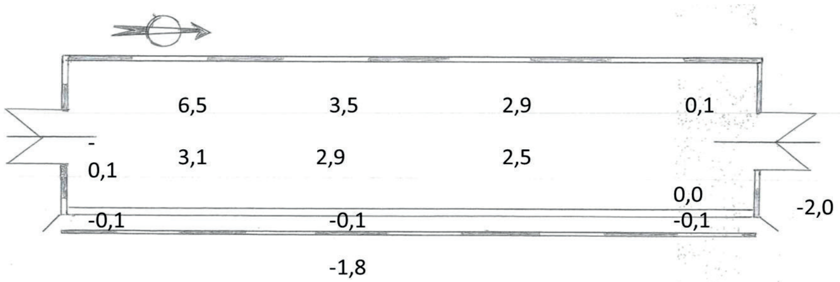

Figure 9. Topography of the floor temperatures in building № 3 during the winter

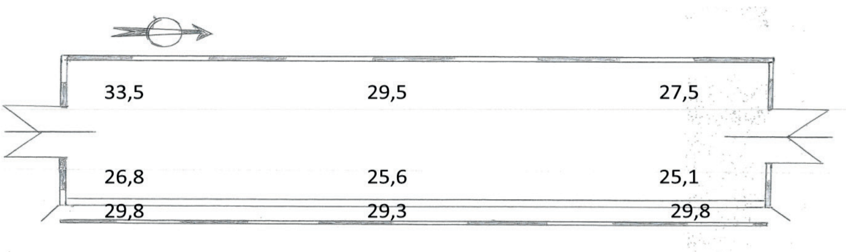

Figure 10. Topography of the floor temperatures in building № 3 during the summer at an outdoor temperature of 35 ºC

The microclimatic factors determine the welfare and the behaviour of the animals, including their lying time. The topographies of the floor temperature during the summer and the winter we made (Figures 5, 6, 7, 8, 9 and 10) characterize the differences in the breeding technologies and the behavioural reactions of the cows. The studies of O'Driscoll et al., (2009) prove that the cows spend more time lying during the winter regardless of the box bedding and the breeding technology. The percentage of lying cows in building № 3 reaches 41 at an average temperature of 2.5ºC. The temperature measured under those cows was 12.5ºC. Overton et al. (2002) report the highest relative share of lying cows at a temperature of minus 15ºC.

Data presented by Plyashtenko and Hohlova (1976) indicate that cows lie down for approximately 40-50% of their time and the number of lying-downs and getting-ups varies between 12 and 14 per day. According to the authors, the cold floor quickly cools the body of the lying cow and its temperature decreases from 37.5ºC to 25ºC for a period of 10-15 minutes.

After the cow gets up, the floor releases up to 2ºC warmth in the air environment of the premises. The high temperatures we measured in buildings № 1 and 2 and in the beddings there during the summer are the reason why the cows mainly group in the zone of ventilator activity in an effort to prolong the time for cooling their bodies by standing up (Hristev et al., 2019). At the same time, 55.2% of the cows from building № 3 prefer lying so as to release the excessive body warmth to the deep and humid bedding.

The significance of the light in breeding dairy cows should not be underestimated, too. The level of illumination ascertained by us in all three farms corresponds to the physiological needs of the animals. According to Trofimov et al. (2016), the duration of the light part of the day during the winter must be 16 hours with an intensity of 200-300 lux. The lack of enough light, regardless of the balanced feeding of the animals may prove to be the leading factor for a weak sexual activity and low impregnation rate.

CONCLUSIONS

The specific microclimate which is formed in each of the buildings is a result of the different stocking density, breeding technology, constructive characteristics and the season. The microclimate in the open buildings is more dependent on the outside environmental factors when compared to the closed ones.

The topography of the floor temperatures reveals the differences in the breeding technologies and forecasts the behavioural reactions of the cows. Therefore, upon the overall assessment of the barn environment comfort, it is necessary to take into account not only the thickness and the nature of the bedding but also the floor temperature.

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