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CUBICLE LYING STRUCTURES AND THEIR THERMO-TECHNICAL COMPARISON

Jana Lendelová, Štefan Pogran, Ivana Knížková, Petr Kunc
Slovak University of Agriculture in Nitra

Abstract. The article deals with texture suitability of floors in cow resting areas from the viewpoint of their thermal properties in barns with cubicles. The following types of planks were chosen for the purposes of evaluating: stalls with raised concrete base with different mattresses and mats, stalls with raised base covered with brick agrofloor or whitewood timber, and deepened stalls filled with straw, laminated sandwich (consisting of separated manure, straw mixed with ground limestone and short cut straw), sawdust or sand. The computation methods for determination of thermal resistance and thermal effusivity were used to evaluate the thermo-technical properties of floors based on valid technical standards. This analysis showed that stalls with deep straw bedding are much more suitable for dairy cows than other types assessed. They reach the high thermal resistance $R = 2.914\ m^{-2}\cdot K\cdot W^{-1}$ and very suitable thermal effusivity $b = 162\ W\cdot s^{1/2}\cdot m^{-2}\cdot K^{-1}$. In order to compare the achieved level of resting animal thermal comfort with regard to selected types of floor texture, temperatures of heated resting areas of dairies were measured using thermovision and a contactless thermometer. After a 30-minute observation of a laying dairy, temperature differences in heating stalls with straw, as determined by practical measurement, were found to belong to a homogeneous group of results characteristic of "warm floors". These floors were covered with foam rubber-filled mattress and insulation mats with rubber coating. Their temperature differences were significantly higher than the temperature differences measured on concrete floor, wooden floor as well as paved brick floor ($P < 0.001$).

Key words: floor structure, thermal properties, floor surface temperatures, heat floor conducting, biological warp

INTRODUCTION

In order to achieve good milk production from a dairy, the dairy needs to obtain needed rest while laying [Brestensky et al. 1998, 1999]. Therefore the thermal conditions of such resting areas are one of the factors affecting laying comfort, and that is why we ought to care about the thermal parameters of floors.

Corresponding author – Adres do korespondencji : Jana Lendelová, Slovak University of Agriculture in Nitra, Department of Building, Akademicka 8, 94976 Nitra, Slovakia, e-mail: Jana.Lendelova@uniag.sk

Low temperatures in stall buildings, in holding space and in milking parlor – may negatively affect the results of milking by the influence of heat loss in building structures [Karas et al. 2002]. In general, winter thermal discomfort may be caused by a structured floor type, which results in a small thermal resistance, but especially high thermal effusivity [Chmúrny 2003].

The heat conduct from the bodies of lying animals in resting areas affects the structural design of a floor and the final thermal effusivity. This process can be ideally solved by non-stationary three dimensional field. However, the problem is to define the thermo-technical properties of an animal body [Šlajs et al. 1995].

In Pogran's opinion [Pogran and Lendelová 2002], an interactive heat investigation between a cow's body and a floor leads to a conclusion that contact temperature decreases rapidly during the first and second minute of laying time. The temperature gradient value from 4 to 15°C is dependent on the structure of the floor. Insulated-thermal properties of planks should provide adequate surroundings in terms of dairy thermal comfort. It is the top floor layer that determines the floor quality, which then directly affects the thermal balance of organism [Šlajs et al. 1995]. The floor thermal properties are assured through the values of thermal resistance and effusivity [Chmúrny 2003]. When calculating thermal effusivity values, it is important to assess how many structured layers will have a demonstrable affect on the final effusivity value; in other words, it is important to know whether there are equivalent single-layer, double-layer or three--layer floor structures [Halahyja et al. 1998].

The aim of this work was to analyze the multilayer floor structures of lying cubicles – with classic natural, or modern artificial beddings – in terms of their thermo-technical properties investigated through theoretical and practical methods.

MATERIAL AND METHODS

The floor surface temperature may be considered a resultant of a reaction on a structure cubicle floor material defined by the thermal resistance and the thermal effusivity values of equivalent single and double-layer structure technique. The calculating methods are showed in STN 73 0540-4, part 4: 'Calculating technique'. The calculation based on equivalent three-layer structure occurs only sporadically on lying cubicle structures. Thermal isolation on lower structured layers – under hydroinsulation – doesn't affect the thermal comfort of resting animals. In contrast, the top floor layer with its thermo-technical properties mostly influences the whole thermal comfort of the resting animal. Therefore we engaged our research into the properties and design of the thickness of this structured part.

The calculation of the boundary structure thickness of equivalent single-layers is done starting from the top layer, which numerically substitutes the whole multi-layer floor structures (a floor layer numbering was done from top to bottom).

The temperature measuring was realized on experimental farms with loose cubicle stalls in groups of 20 dairies. Thermal measuring was applied using a thermovision camera AGA 570 DEMO and a non-contact thermometer RAYTEK ST 60. An experiment was carried out in winter, with temperature of internal air θ_{ai} = +5°C (±1°C).

Thermal profile evaluation was made by special software Irwin 5.3.1. Microclimatic parameters (air temperature, relative humidity and air circulation speed) were recorded continuously using ALMEMO machine.

The following types of resting areas were chosen for the purposes of evaluating: deepened stalls filled with straw, sawdust or sand, stalls with raised concrete base with different mattress or mats, and stalls with raised base covered by brick agrofloor or whitewood timber.

The recording of instant surface cradle temperatures after the restage of a dairy was used in the procedure. Such acquired data was considered to be the result of the living organism's thermal action upon the underlay, due to its own various thermo-technical natures. When evaluating the results, we utilized the fact that in defined material environment, the surface temperature of the floor structures, in general, represents the internal thermal response of the time – limited action.

In primary measurements, the initial comparisons of the point-sampling (acquired by the non-contact thermometer), and the planar thermovision sampling were evaluated first. From the early results, it was certain that the thermal paths of the underlay, after it was heated by the laying dairy, are stably irregular; and therefore a unified, circular shaped area for observing was established for all the following measuring and evaluations (Fig. 1). The temperatures were recorded prior at the entrance of the dairy to

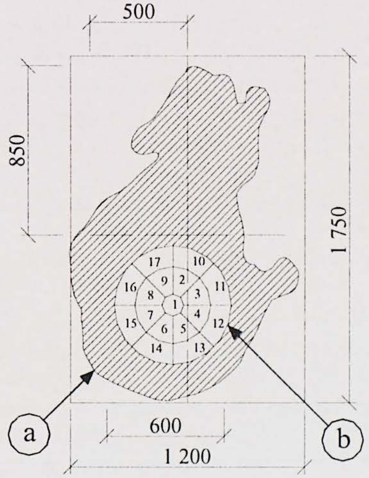


Fig. 1. The principle of the work with the additional template used for the measuring of the surface on the thermal path in the cubicle. The parameters of the template were acquired after processing the thermal records and the measuring of the contact surface (a) of the laying dairy with the underlay. The circular template (b) was shifted from the vertical axis according to whether the observed dairy laid on its left, or right side

Rys. 1. Zasada pracy z dodatkowym szablonem używanym do pomiaru powierzchni na torze cieplnym w legowisku. Parametry szablonu określono po rejestracji temperatury i pomiaru powierzchni kontaktowej (a) bydła leżącego z warstwą izolującą. Szablony okrągłe (b) zostały zmienione z pionowych na lewo- lub prawostronne odpowiednio do pozycji leżenia bydła the cubicle, and after the resting. The recording of the time period of the resting dairy began as soon as the dairy made a contact with the surface of the underlay. The termination was either forced, or spontaneous. When forced, the dairies were instructed to stand up by the observer, after 1800 s (30 min), or 2700 s (45 min). Some of the dairies, however, took off early from the underlay, or they refused to leave in the established time period. The objective time, which differed, was recorded.

That is how the following 2 types of temperature measuring developed, which we used in all the examined floor structures:

1. Measure of the temperature differences created by the warmed underlay during resting, in the span 30 min and 45 min as the dairy laid down.

2. Measure of the temperature differences after the warming during various periods of resting form 600 to 3600 s (10–60 minutes).

The initial contact temperature of the dairy's body was considered to be 31°C in reference to previous researches. Due to the chance of random error of the calibration of the individual applied facilities, the temperature differences were used with the statistical evaluation.

RESULTS AND DISCUSSION

As expected from the thermo-technical point of view, the calculate analysis showed that concrete floor structures with 200 mm of straw bedding are much more suitable for laying animals than other types assessed. They reach the high thermal resistance $R = 2.914\ m^2 \cdot K \cdot W^{-1}$ and very suitable thermal effusivity $b = 162\ W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$ (Tab. 1). In Brestensky's opinion [Brestensky et al. 1998], deepened cubicles filled with straw litter are very suitable for dairy, if straw is maintained clean and dry.

Table 1. Resulting of thermal effusivity (b) $[W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}]$ and thermal resistant (R) in selected sorts of lying structures

Tabela 1. Wyniki efektywności cieplnej (b) $[W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}]$ i oporu cieplnego (R) w wybranych rodzajach legowisk

Floor category according to STN 73 0540-2 Kategoria posadzki wg STN 73 0540-2	Floor classifying according to thermal effusivity (b) $[W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}]$ and thermal resistance, R $[m^2 \cdot K \cdot W^{-1}]$ Klasyfikacja posadzek wg efektywności cieplnej (b) $[W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}]$ i oporu cieplnego R $[m^2 \cdot K \cdot W^{-1}]$			
1	2	3	4	5
Standard values of effusivity Standardowe wartości efektywności	b	R	Floor N Posadzka N	Floor structure type Typy posadzek
I Very warm Bardzo ciepłe $b_N \leq 350$	144	1,724	5	High concrete floor with mattress filling by Styropor (rubber – foam from shoe-scrap) Posadzka betonowa podwyższona z materacem wypełnionym styroporem (pianka gumowa)

Table 1 cont.
Tabela 1 cd.

1	2	3	4	5
	162	0,343	4a	High concrete floor with 20 mm layer of dry straw Posadzka betonowa podwyższona z 20 mm warstwą słomy
	162	2,914	4b	Deepened concrete floor with 200 mm layer of dry straw Posadzka betonowa pogłębiona z 200 mm warstwą słomy
	162	0,431	6	High concrete floors with agro-brick-floor with 20 mm layer of dry straw Posadzki betonowe podwyższone z posadzką ceglaną z 20 mm warstwą słomy
	245	1,724	2a	Deepened concrete floor with 200 mm sawdust filling Posadzka betonowa pogłębiona z 200 mm wypełnieniem trocinami
II Warm Ciepłe $b_N = 351 - 700$	422	0,175	3	High concrete floor with 20 mm biological warp Posadzka betonowa podwyższona z 20 mm obornikiem
	422	0,449	8	High concrete floor with 50 mm wooden top-layer with biologic. warp Posadzka betonowa podwyższona z 50 mm wierzchnią warstwą drewnianą z obornikiem
	424	0,909	4d	Deepened concrete floor with 200 mm layer of dampy straw Posadzka betonowa pogłębiona z 200 mm warstwą wilgotnej słomy
	474	0,148	4c	High concrete floor with 20 mm layer of dampy straw Posadzka betonowa podwyższona z 20 mm warstwą wilgotnej słomy
	459	0,331	7	High concrete floor with 40 mm top layer of white-wood timber Posadzka betonowa podwyższona z 40 mm wierzchnią warstwą z drewna
	522	0,682	1	High concrete floor and 100 mm mattress with recycled rubber filling Posadzka betonowa podwyższona i 100 mm materac wypełniony gumą z recyklingu
	522	0,734	9	High concrete floor covered insulating matt 35 mm and 15 mm of rubber protective belt Posadzka betonowa podwyższona pokryta matą izolującą 35 mm i 15 mm gumą
	607	0,238	10b	High concrete floor with water mattress covered by 5 mm of biological warp Posadzka betonowa podwyższona z materacem wodnym pokryta 5 mm obornikiem
III Less warm Mniej ciepłe $b_N = 701 - 850$	706	0,209	10a	High concrete floor with water mattress (rubber 4.7 mm, water 34.6 mm and rubber 4.7 mm) in clean condition Posadzka betonowa podwyższona z materacem wodnym (guma 4,7, woda 34,6 i guma 4,7 mm) bezściołowa
IV Cold Zimne $b_N > 850$	1243	0,268	2b	Deepened concrete floor with 200 mm of sand filling Posadzka betonowa pogłębiona z 200 mm piaskiem
	1882	0,057	2	High cleaned concrete cubicle floor Posadzka betonowa podwyższona bezściołowa

In our research, we determined that trials with moisturized straw influenced the reduced thermal resistance $R = 0.909\ m^2 \cdot K \cdot W^{-1}$, thermal effusivity $b = 424\ W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$. Therefore it is important to remove the wet particles off the underlay not only due to hygienic reasons, but also in order to ensure thermo-technical requirements.

The coldest floor from all the investigated types was the concrete one (thermal resistance was specified by value $R = 0.057\ m^2 \cdot K \cdot W^{-1}$ and the thermal effusivity $b = 1882\ W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$). However, in practice such cubicle laying surfaces do not under normal circumstances occur in absolutely clean conditions in a non-bedding raising system of dairies. The biological accretion (made out of dry manure with cow hair and small parts of food) on lying cubicles causes higher surface temperatures – analogous to values of rubber materials. The biological warp is a layer formed by sequential application of delicate manure layers by cow's hooves on the floor surface. This part of a cubicle underlying is being compressed every time as the weight of a cow's body pressures it down (near 4.7 kPa) at the same time as the cow's body temperature (32–39°C) contributes to this process as well.

In daily used cubicles, this layer grows little by little and everyday, but the surface is flattened by animals that are frequently getting up and down. If the warp is formed directly on to the concrete floor, its resultant thermal effusivity during growing manure thickness, which varies from 0 to 17 mm, makes it more then four times better. More bulky warps than the boundary value of equivalent single-layer of manure will not improve final thermal effusivity values.

In terms of the thermal comfort of dairy resting areas, however, both of the used methods have revealed that a category of the so-called "cold floors" is missing in practice. For example, in civil buildings concrete is unquestioningly a "cold floor" ($b = 1880\ W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$) but as for cow concrete resting areas, there was a fourfold improvement due to thermal-insulation properties of a solid, dry biological warp ($b = 422 \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$ if it's thickness $d_m \geq 0.017$ m). A similar process can be observed in all types of resting areas without bedding, except for non-suitable slippery top layers which are difficult for the warp to be caught on.

With regard to protecting the cows from the cold, which is secured by thermal effusivity, it is very important to respect "the limit thickness" of an equivalent single-layer floor structure (as minimum). It is represented by bulk litter material with thickness between 10 and 30 mm in general. Consequently, if the material of top layer is accepted by animals and it is also thermo-technically suitable, its thickness should be bigger than the limit thickness value. The boundary structure thicknesses of equivalent single-layers for various materials and the thermal absorptive capacity for each shows Table 2.

Good thermal-technical parameters were observed on the floors with rubber top layer, whether it was mattresses or mats; the mattress filled with recycled foam rubber scrap arising from shoe manufacture were found to approach most the deepened resting areas with straw bedding ($R = 1.724 \cdot m^2 \cdot K \cdot W^{-1}$, $b = 144\ W \cdot s^{1/2} \cdot m^{-2} \cdot K^{-1}$).

While observing the process of heating up within 30 minuets since the dairy has lain down, we figured out that the worst results ($\Delta\theta_2 = 11.29$ K) were recorded on cleaned concrete resting areas. The temperature differences of this floor construction were significantly lower ($P < 0.001$) in comparison to all the other floors. The differences on a concrete floor covered with a layer of biological coat was $\Delta\theta_3 = 15.09$ K, and the recorded temperature differences after a 30 minute rest weren't any statistically different with the wooden floors as well as paved brick floors.

Table 2. The boundary structure thicknesses of "equivalent" single-layers for various materials and the thermal absorptive capacity for each

Tabela 2. Grubość graniczna równoważnych pojedynczych warstw dla różnych rodzajów materiałów i pochłaniania cieplnego dla każdej warstwy

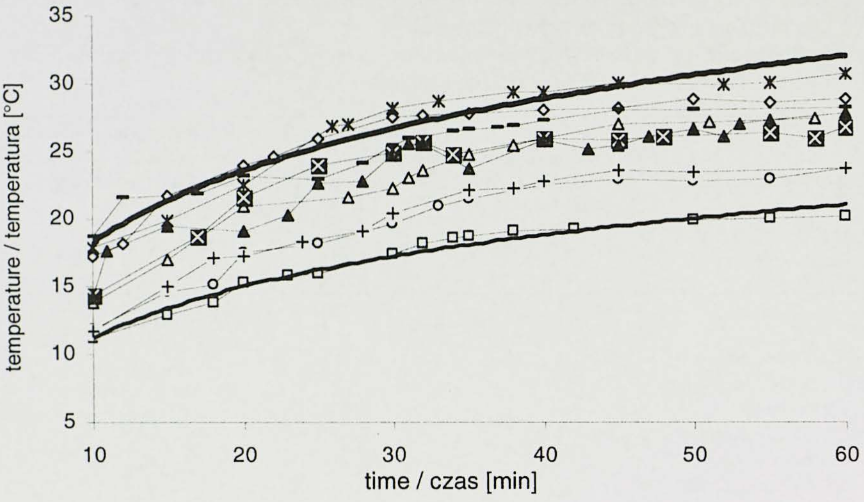
Material of the top structured layer Materiał wierzchniej warstwy	Minimum top layer thickness Minimalna grubość wierzchniej warstwy $d_1 = \sqrt{3a_1 t}$ [m]	Thermal effusivity for equivalent single-layer structure Efektywność cieplna dla odpowiednich pojedynczych warstw $b_1 = \sqrt{c_1 . \rho_1 . \lambda_1}$ $[Ws^{1/2}m^{-2}K^{-1}]$
Straw Słoma	0.018	162.3
Recycled rubber mattres Materac z gumy z recyklingu	0.013	522.3
Foam-rubber mattres Materac z pianki gumowej	0.017	141.9
Biological Accretion Uwarstwienie biologiczne	0.017	432.8
Sawdust Trociny	0.0189	224.0
Hard wood Drewno twarde	0.022	795.2
Sand Piasek	0.0243	1243.5

The most suitable results were recorded on concrete floor with a mattress of recycled rubber, and a concrete floor with STYROPOR mattress; in both of these after 30 minute long rest the surface temperatures of the resting areas were increased by $\Delta\theta_1 = 19.81$ K, resp. $\Delta\theta_5 = 20.51$ K. The position of this floors in the timed behavior of surface temperatures of all measured varieties shows Figure 2. Similarly these floors were also evaluated with the 45 minutes long resting time of the dairies (Tab. 3).

CONCLUSION

If such floor construction that provides softness and elasticity of top laying floor structure (straw, sawdust, separated manure, rubber foam...), there are also usually well ensured thermo-technical properties.

Applied data collection of temperature difference of the warmed resting areas with straw were for all significance levels of 30 minute long observations found to be a part of the homogenous series with the results of characteristically warm floors covered with mattresses filled with rubber foam and isolating mat with rubber cover. Their temperature differences were significantly higher than the temperature differences measured on concrete floor, wooden floor as well as paved brick floor ($P < 0.001$).



diamond – N1 – High concrete floor and 100 mm mattress with recycled rubber filling
romb – N1 – Posadzka betonowa podwyższona i 100 mm materac wypełniony gumą z recyklingu
square – N2 – High cleaned cubicle floor
kwadrat – N2 – Posadzka betonowa podwyższona bezściołowa
triangle – N3 – High concrete floor with 20 mm biological warp
trójkąt – N3 – Posadzka betonowa podwyższona z 200 mm obornikiem
cross – N4 – Deepened concrete floor with 200 mm layer of dry straw
krzyż – N4 – Posadzka betonowa pogłębiona z 200 mm warstwą słomy
star – N5 – High concrete floor with mattress filling by Styropor
gwiazda – N5 – Posadzka betonowa z materacem wypełnionym styroporem
circle – N6 – High concrete floors with agro-brick-floor with 20 mm layer of dry straw
okrąg – N6 – Posadzki betonowe podwyższone z posadzką ceglaną z 20 mm warstwą słomy
plus – N7 – High concrete floor with 40 mm top layer of whitewood timber
plus – N7 – Posadzka betonowa podwyższona z 40 mm warstwą wierzchnią z drewna
fill triangle – N8 – High concrete floor with 50 mm wooden top-layer with biologic. warp
pełny trójkąt –N8 – Posadzka betonowa podwyższona z 50 mm wierzchnią warstwą drewnianą z obornikiem
minus – N9 – High contr. floor covered insul. matt 35 mm and 15 mm of rubber protect. belt
minus – N9 – Posadzka betonowa podwyższona pokryta matą izolującą 35 mm i 15 mm gumą

Fig. 2. The position of the confronted floor N 5 in the timed behavior of surface temperatures of all the measured varieties of surfaces

Rys. 2. Porównanie zachowania się termicznego w czasie posadzki N 5 z innymi rodzajami posadzek

Table 3. Results of the collected data of the temperatures at the earlier defined time intervals
Tabela 3. Wyniki temperatur na początku interwału czasowego

Floor Number Nr posadzki P	$\bar{x}$	*s.d.*	*s.e.*	*v*	min	max	*F-test*
Difference in temperature after 30 minute long resting period of dairies on various floors [K] Różnica temperatury po 30-minutowym okresie spoczynku bydła mlecznego na różnych posadzkach [K]							
1	19,81	1,57	0,45	7,93	17,78	22,70	$F^{30} = 85,02$***
2	11,29	0,70	0,22	6,17	10,09	12,46	$P^{30} < 0,001$
3	15,09	1,65	0,41	10,93	11,63	18,21	P_1: P_8,P_3,P_7,P_6,P_2***
4	18,91	0,99	0,30	5,25	17,79	21,06	P_2:$P_5,P_1,P_9,P_4,P_8,P_3,P_7,P_6$***
5	20,51	0,57	0,16	2,78	19,87	21,56	P_3: P_5,P_1,P_9,P_4,P_8, P_2***
6	13,67	1,16	0,32	8,49	12,26	15,58	P_4: P_3,P_7,P_6,P_2***
7	13,83	0,77	0,23	5,60	12,67	15,14	P_5: P_8,P_3,P_7,P_6,P_2***
8	17,73	1,35	0,32	7,60	14,79	20,37	P_6: P_5,P_1,P_9,P_4,P_8, P_2***
9	19,13	1,12	0,32	5,84	16,91	21,07	P_7: P_5,P_1,P_9,P_4,P_8, P_2***
							P_8: $P_5, P_1, P_3,P_7,P_6,P_2$***
							P_9: P_3,P_7,P_6,P_2***
Total	16,74	3,15	0,29	18,82	10,09	22,70	
Difference in temperature after 45 minute long resting period of dairies on various floors [K] Różnica temperatur po 45-minutowym okresie spoczynku bydła mlecznego na różnych posadzkach [K]							
1	20,62	1,28	0,45	6,23	18,59	22,10	$F^{45} = 59,14$***
2	12,71	0,76	0,27	5,97	11,83	13,98	$P^{45} < 0,001$
3	20,81	1,71	0,47	8,21	18,90	24,02	P_1: P_8,P_4,P_7,P_6,P_2***; P_1: P_5**
4	19,77	1,23	0,39	6,20	17,80	21,12	P_2 : P_5,P_9,P_3,P_1,P_8, P_4***
5	23,10	1,42	0,47	6,15	20,67	24,87	P_2:P_7,P_6**
6	15,27	1,27	0,40	8,33	13,33	17,23	P_3: P_8,P_4,P_7,P_6,P_2***; P_1: P_5**
7	16,78	0,94	0,31	5,61	15,04	18,11	P_4: P_5,P_7,P_6,P_2***; P_1:P_9*
8	19,79	1,48	0,38	7,50	17,51	22,67	P_5,: P_8,P_4,P_7,P_6,P_2***; P_5: P_1,P_3**
9	21,70	0,94	0,30	4,35	20,41	23,20	P_6: $P_5,P_9,P_3,P_1, P_8, P_4$***; P_6: P_2**
							P_7: $P_5,P_9,P_3,P_1, P_8, P_4$***; P_7: P_2**
							P_8,: P_5,P_7,P_6,P_2***;P_1:P_9*
							P_9,: P_8,P_4,P_7,P_6,P_2***; P_9: P_1,P_3**
Total	19,13	2,83	0,36	16,82	11,83	24,87	

Explanations: n – the number of measurements; $\bar{x}$ – the average value of the difference in temperature [K], s.d. – is the standard deviation, s.e. – mean error, *v* – the calculus coefficient, min – the minimum value, max – is the maximum value

Oznaczenia: n – liczba pomiarów, x – średnia wartość różnicy temperatur; s.d.– odchylenie standardowe; v – błąd średni; *v* – współczynnik obliczeniowy; min – wartość minimalna; max – wartość maksymalna

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LEGOWISKA W ZABUDOWIE BOKSOWEJ PORÓWNANIE ICH WŁASNOŚCI CIEPLNO-TECHNICZNYCH

Abstrakt. W pracy przedstawiono przydatność posadzek w aspekcie ich własności cieplnych w miejscach wypoczynku krów. Do oceny wybrano następujące typy materiałów: przegrody z podkładem betonowym z różnego rodzaju matami i materacami, przegrody z podstawą pokrytą cegłą lub jasnym drewnem oraz przegrody pogłębione wypełnione słomą, z wieloma warstwami (obornik, słoma z wapnem i pociętymi kawałkami słomy), piasku lub trocin. Do oceny własności cieplno-technicznych posadzek użyto metod obliczeniowych w celu określenia oporu cieplnego i efektywności cieplnej. Analizy wykazały, że przegrody z głęboką ściółką są o wiele bardziej przydatne dla krów mlecznych niż dla pozostałych zwierząt. Osiągają wysoki opór cieplny i odpowiednią efektywność cieplną. W celu porównania uzyskanego poziomu komfortu cieplnego odpoczywających zwierząt dokonano pomiaru temperatury ogrzewanych miejsc wypoczynkowych przewidzianych dla krów mlecznych przy zastosowaniu termowizji i termometru. Po 30-minutowej obserwacji leżących krów mlecznych różnice temperatury w ogrzewanej przegrodzie przyporządkowano do jednorodnej grupy wyników charakteryzujących „posadzki ciepłe". Posadzki te pokryte były materacami wypełnionymi pianką gumową i matami izolacyjnymi z warstwą gumową. Wykazane różnice temperatury były istotnie wyższe niż różnice temperatury mierzone na posadzce betonowej, drewnianej oraz ceglanej. ($P < 0,001$).

Słowa kluczowe: budowa posadzki, własności cieplne, temperatura powierzchni posadzki, przewodzenie ciepła w posadzce, wypalacz biologiczny

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