Abstract no.: 5443
Session: S.34 : Livestock Farming Systems Free Communications

Title: Organic bedding materials for cattle barns and their thermo technical properties in different climate conditions.

Author: Lendelova, J. – Mihina, S. – Pogran, S.
Slovak University of Agriculture in Nitra,
Faculty of Engineering, Slovakia

E-mail address: Jana.Lendelova@uniag.sk, Stefan.Mihina@uniag.sk, Stefan.Pogran@uniag.sk

Abstract
Thermo-technical properties of organic materials (straw, sawdust, separated slurry with thickness of 200 mm on concrete base) in comparison to rubber mats and rubber foam mattresses used for bedding of cubicles for dairy cows were evaluated. Thermal resistance and thermal effussivity were calculated according to official technical standards. Coefficient of thermal conductivity needed for these calculations were obtained in real conditions of experimental farms. A thermal resistance of straw varied from 0.91 to 2.91 $m^2.K.W^{-1}$, wooden sawdust from 0.63 to 1.724 $m^2.K.W^{-1}$, separated slurry from 0.85 to 1.22 $m^2.K.W^{-1}$, and rubber mattresses and mats from 0.76 to 1.61 $m^2.K.W^{-1}$. Data of a thermal effussivity of straw were from 162.34 to 423.63 $Ws^{1/2}m^{-2}K^{-1}$, wooden sawdust 333.5 to 773.52 $Ws^{1/2}m^{-2}K^{-1}$, separated slurry from 308.97 to 469.36 $Ws^{1/2}m^{-2}K^{-1}$, and rubber mattresses and mats from 144 to 552 $Ws^{1/2}m^{-2}K^{-1}$. Data were collected both in summer and winter condition and both with dry and wet organic materials.

Key words: cubicles, bedding, thermal resistance, thermal effusivity

Introduction
Proper flooring management and freestall design is a critical for the effective control of production parameters, cow health, longevity and comfort. Many studies have investigated the bedding preferences of dairy cows by comparing different types of floor structures (Palmer et al., 2003; Wechsler et al., 2000; Tucker et al. 2003, and others). Results of similar experiments indicate that cows prefer stalls with softer, elastic, dry and slip resistant floors. A variety of flooring surfaces are used on dairy farms, but not much is known about their impact on the thermal comfort of cattle. Dairy cow free stalls have traditionally been bedded with different organic materials or synthetic products available locally. Bedding material has ranged from straw, wood chips, dolomitic limestone and sawdust to separated manure solids. Organic bedding materials on dry condition are characterized with a big absorbability and low thermal conductivity. However, most organic bedding materials support bacterial growth (Russell et al., 2002). Control of bacteria growth means depriving bacteria of substrate for their growth: moisture, organic matter, and proper temperature and pH. These properties also affect thermotechnical magnitudes (Chmúrny, 2003). Thermal comfort during lying is caused by a structure of bed characterised by thermal

resistance and thermal effusivity. Thermotechnical condition in stables is non-stationary process caused by climatic conditions and farm management (Pogran, 2000).
The aim of this work was to evaluate the thermo-technical properties of organic materials (straw, sawdust, separated slurry with thickness of 200 mm on concrete base) in comparison to rubber mats and rubber foam mattresses used for bedding of cubicles for dairy cows.

Material and Methods
Thermotechnical properties of five different cubicle floor of bed structures were tested in Slovak farms. Three cubicles with deepened concrete stall base were covered by 200 mm layer of straw, sawdust and separated manure, respectively (fig. 1) and two once with elevated concrete stall base covered by rubber mats and rubber foam mattresses(fig. 2), respectively were used.
Thermal resistance and thermal effussivity were calculated according to official technical standards. Data needed for the calculations were obtained in real conditions of experimental farms, both in summer and winter conditions and both with dry and wet organic materials.

The thermal resistance was calculated as follows:

$$R = \sum_{j=1}^{n} R_j = R_1 + R_2 + ... + R_n = \sum_{j=1}^{n} \frac{d_j}{\lambda_j} = \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + ... + \frac{d_n}{\lambda_n}, \quad m^2.K.W^{-1}$$

where R_j – thermal resistance of „*j*“ floor layer, $m^2.K.W^{-1}$
d_j – thickness of „*j*“ layer, m
λ_j – thermal conductivity coefficient „*j*“ layer, $W.m^{-1}.K^{-1}$

Thermal effusivity for one layer equivalent structure of cubicle bed was calculated as follows:

$$b = \sqrt{\lambda.c.\rho}, \quad W.s^{1/2}.m^{-2}.K^{-1}$$

where c - specific thermal capacity, $J.kg^{-1}.K^{-1}$
ρ - bulk density, $kg.m^{-3}$

Thermal effusivity for two layer equivalent structure of cubicle bed was calculated as follows:

$$b = b_1(1 + K_{1,2}), \quad W.s^{1/2}.m^{-2}.K^{-1}$$

where

$$K_{1,2} = f\left(\frac{b_2}{b_1}, \frac{d_1^2}{a_1.\tau}\right)$$

where

b_1 - is thermal effusivity of first floor layer in $W.s^{1/2}.m^{-2}.K^{-1}$
b_2 - is thermal effusivity of second floor layer in $W.s^{1/2}.m^{-2}.K^{-1}$

$$b_1 = \sqrt{\lambda_1.c_1.\rho_1}, \quad b_2 = \sqrt{\lambda_2.c_2.\rho_2}$$

„Boundary“ structure thickness was calculated as follows:

$d_{1m}= 42,4 \,.\, \sqrt{a_1}$, m

where

a_1 – is thermal diffusivity factor

$$a_1 = \frac{\lambda_1}{c_1 . \rho_1} \;,\; m^2.s^{-1}$$

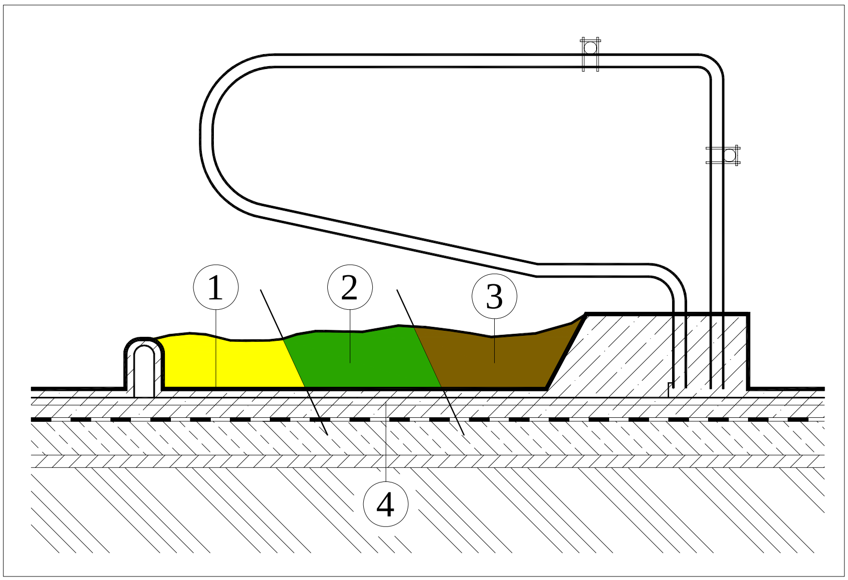

Fig. 1 Deepened stall base cubicle bedded by organic materials
1 – straw, 2 – sawdust, 3 – separated slurry, 4 - concrete

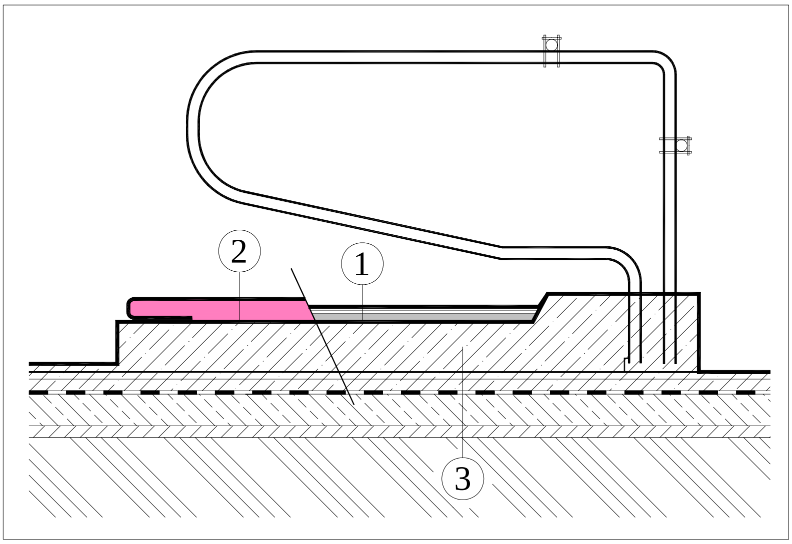

Fig. 2 Elevated stall base cubicle covered by synthetic materials
1 – rubber mats (35 mm of insulation flexible recycled material, 15 mm of rubber covering),
2 – rubber foam mattress (100 mm of rubber crushed recycled or foam material with special cover)
3 – concrete

Results

Thermotechnical parameters varied according to climatic conditions and farm management (Fig. 3. and Fig. 4). Very good results were found in all dry organic material. They had very good absorption and cushioning. Average value of a thermal resistance (R_{dry}) varied from separated slurry (1.22 $m^2.K.W^{-1}$) to dry straw (2.91 $m^2.K.W^{-1}$) and thermal conductivity coefficient (λ_{dry}) from 0.06 to 0.16 $W.m^{-1}K^{-1}$. The organic beddings investigated in wet conditions had their thermal resistance (R_{wet}) from 0.63 to 0.910 $m^2.K.W^{-1}$, and thermal conductivity coefficient (λ_{wet}) from 0.23 to 0.32 $W.m^{-1}K^{-1}$.

The rubber mats and mattresses has lower thermal resistance (0.76 to 1.61m^2KW^{-1}), as dry organic materials. However, it was much more larger and better than concrete base without any bedding (0.12 $m^2.K.W^{-1}$).

Data of a thermal effussivity had a similar tendency as in thermal resistance data. Again, the best among organic materials was dry straw (162.34 $Ws^{1/2}m^{-2}K^{-1}$). The thermal effusivity of rubber foam mattresses was little bit better than dry straw (144.35 $Ws^{1/2}m^{-2}K^{-1}$). All investigated materials had many times better thermal effusivity than concrete not covered by any bedding (from 144.35 to 773,52 $Ws^{1/2}m^{-2}K^{-1}$, in comparison to 1880 $Ws^{1/2}m^{-2}K^{-1}$).

Thermal comfort would be improved on synthetic materials by spreading of a little organic material (Fig. 5). It can also absorb moisture and increase cleanness and hygiene of cubicle bed.

Conclusions

- All types of investigated bedding materials improved thermotechnical properties of cubicle bed both from their thermal resistance and thermal effusivity point of view.
- Better thermal comfort can be expected in organic materials, straw first of all, however, in drier weather condition.
- Rubber foam mattresses have thermotechnical properties comparable to straw.
- Thermal comfort would be improved on synthetic materials by spreading of a little organic material. It can also absorb moisture and increase cleanness and hygiene of cubicle bed.

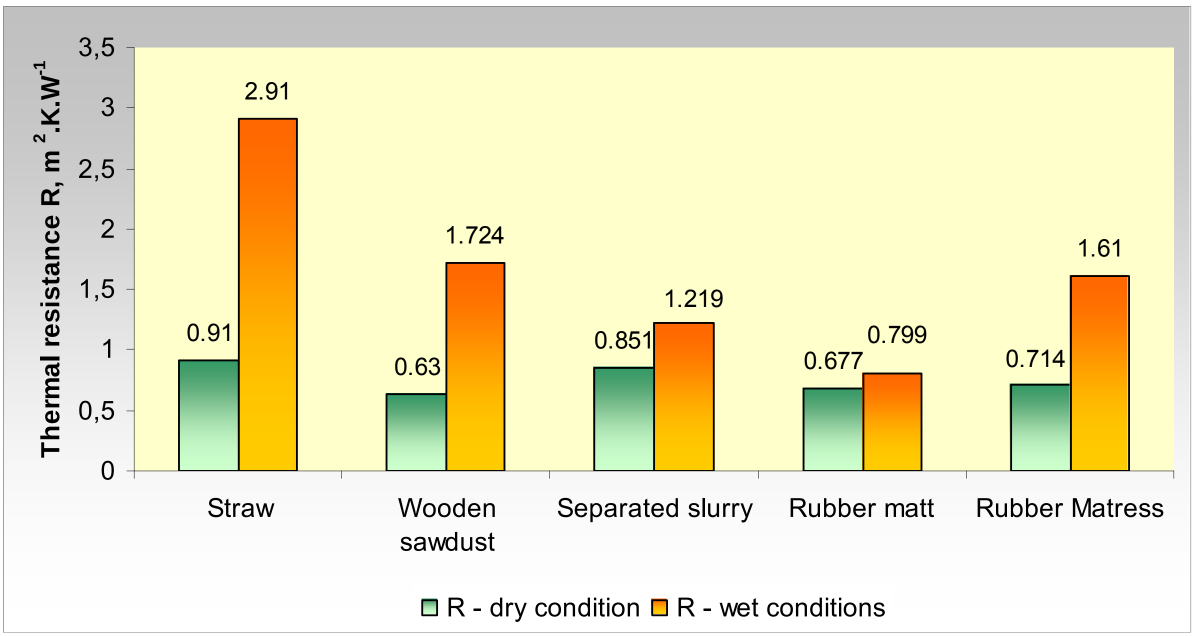

Fig. 3 Thermal resistance of different types of bedding in cubicles.

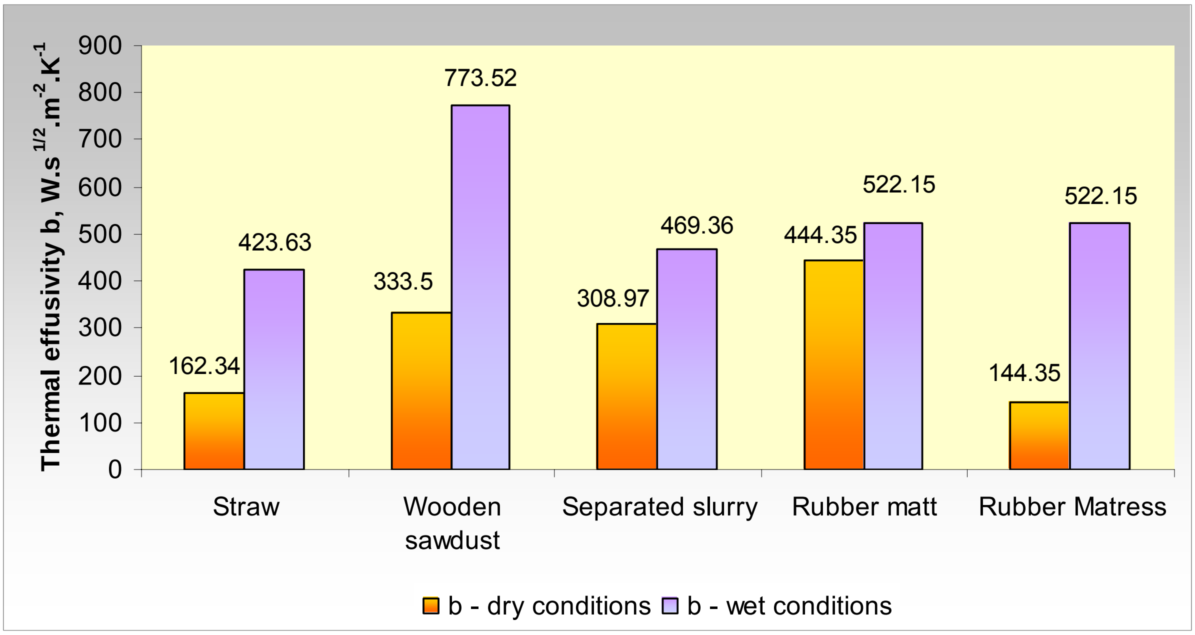

Fig. 4 Thermal effusivity of different types of bedding in cubicles

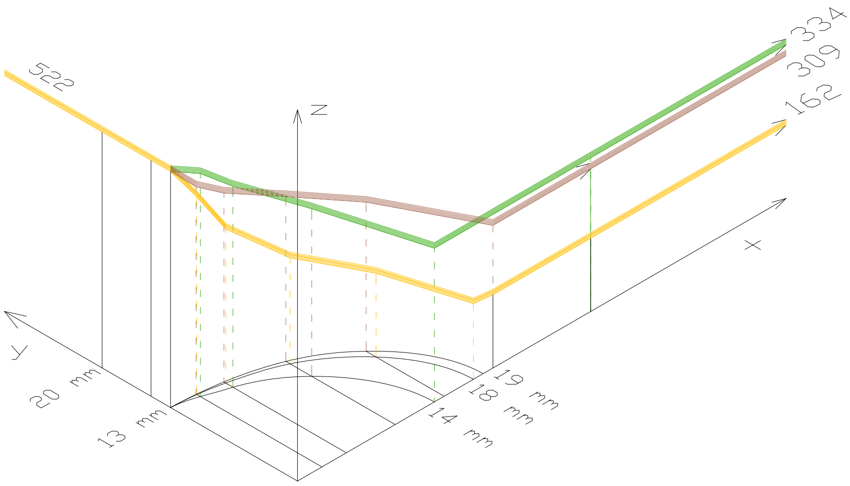

Fig. 5 Changes in thermal effusivity by adding straw (yellow), sawdust (green), or separated slurry (brown) on rubber surface in dry conditions.

x – thickness of first layer floor structure with organic bedding

y – thickness of second layer structure from rubber

z – thermal effusivity, Ws $^{1/2}$ m^{-2} K $^{-1}$

Contacting address:

Ing. Jana Lendelová, PhD., prof. Ing. Štefan Mihina, PhD., doc. Ing. Štefan Pogran, PhD.

– Slovak University of Agriculture in Nitra – Faculty of Engineering.

Jana.Lendelova@uniag.sk, Stefan.Mihina@uniag.sk, Stefan.Pogran@uniag.sk

References

CHMÚRNY, I. 2003. Tepelná ochrana budov. Bratislava : Jaga group, 2003. 214 p. ISBN 80-88905-27-3.

PALMER, R. W. – WAGNER-STORCH, A. M. 2003. Cow Preference for Different Freestall Bases in Pens withDifferent Stocking Rates. Proc. From the Fifth International Dairy Housing Conference. ASAE, St. Joseph, MI.pp. 155-164

POGRAN, Š., LENDELOVÁ, J., VERNAREC, J. 2000b. Analýza vplyvu vlhkosti na stavebné materiály v ustajňovacích objektoch. In Construmat 2000. Nitra : SPU, 2000, p. 154-158.

RUSSEL, B. F., J. K. RENAU, Farnsworth, R. J. 2002. The role of bedding management in udder health. Proceedings of the 41st Annual Meeting of the National Mastitis Council, p. 45-55.

TUCKER, C. B., WEARY, D. M., FRASER, D. 2003. The effects of Three Types of Free-Stall Usage by Dairy Cows. In: J. Dairy Sci., vol. 86, 2003, p. 521-529.

WECHSLER B., SCHAUB J., FRIEDLI K., HAUSER R. 2000. Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. In Applied Animal Befaviour Science, vol. 69, 2000, p. 189-197.