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THE DISTRIBUTION OF DEEP-LITTER TEMPERATURE IN A DAIRY BARN

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Abstract

The paper presents results of studies of some indoor microclimate parameters and temperature of litter bedding in a freestall barn used to house dairy cattle in a deep-litter bedding system. The studies were conducted in the period from 22 March 2014 to 22 March 2015. The analysis of distribution of litter surface temperature showed its strong relationship with indoor air temperature. In summer, temporary exceedances of the allowable indoor air temperature by even 12 °C were noted. The studies showed a significant effect of the number of animals in the barn on litter surface temperature. In the periods when cows stayed in the barn, two zones could be distinguished: the sidewall zone 1.5 m wide at the western outside wall of the building and the inner zone encompassing the remaining part of the barn. Differences in litter temperature between these zones, when cows stayed in the barn, reached 10°C. When the building was empty and animals were on pasture, the differences between litter surface temperatures were much smaller and did not exceed 3°C.

Keywords: barn, deep-litter bedding, litter temperature

INTRODUCTION

The environmental conditions, which preserve well-being of dairy cows, have a considerable influence on immunity of animals to diseases and milk production (Solan and Jóźwik 2009, Mroczkowski 2006). These conditions are defined principally by microclimate of the barn interior and housing system of cows.

Proper indoor air temperature and humidity conditions in the barn depend mostly on ventilation efficiency (Herbut *et al.* 2015, Nawalany 2012). It is particularly important in summer when air changes per hour should range from $40 \cdot h^{-1}$ to $60 \cdot h^{-1}$ in order to minimize the risk of excessive rise in air temperature and relative humidity (Herbut *et al.* 2012). If ventilation system works inefficiently, comfort of cows is compromised thus increasing the risk of reduction in milk production efficiency by ca. 15% and elevating the feed consumption by over 30% (Fiedorowicz and Mazur 2011). The optimal air temperature range in a barn amounts to – 7÷18°C. Indoor relative humidity should range from 60% to 80%. In periods when indoor temperature in the barn is above 25°C while indoor air relative humidity exceeds 80%, there is a risk of heat stress in dairy cattle (Jaśkowski *et al.* 2005, Daniel 2008). In summer, the risk of heat stress in cows is much greater due to prolonged periods of high temperature and inability of cattle to dissipate excess heat to the environment (Nawalany and Sokołowski 2015, Sokołowski and Nawalany 2016). Relationship between air temperature and relative humidity has been investigated in many studies by using the temperature-humidity index (THI) (Herbut and Angrecka 2012, Akyuz *et al.* 2010, Bohmanova *et al.* 2007, Bouraoui *et al.* 2002).

Apart from barn microclimate, the housing system chosen by a farmer is another factor influencing the comfort of dairy cattle. In the last five decades, a huge technological progress has been made in dairy cow housing systems, both in terms of design of the whole facilities and the detailed technical and functional aspects (Winnicki *et al.* 2003). Studies aimed to improve thermal conditions in resting area of dairy cows with the use of calculation models are also in progress (Radoń *et al.* 2014).

Deep-litter farming system improves animal welfare particularly in highly productive dairy farms during cold weather (Chodanowicz *et al.* 2009). Barns with deep-litter bedding require most of all litter storage space and constant filling of stalls with the bedding material. If the amount of litter increases too fast, it may be necessary to remove it during the production period, which can create a problem with providing the animals with an alternative space during litter removal (Kapuinen 1993). Emissions of greenhouse gases, like CO_2, CH_4 and N_2O from a deep-litter farming system vary depending on litter removal frequency rate (Mathot *et al.* 2016) and indoor air temperature (Pereira *et al.* 2012). Welfare of animals staying in the barn is significantly influenced by temperature and litter thickness, which change throughout the year.

AIM AND SCOPE OF RESEARCH

The aim of the study was to analyse the distribution of litter surface temperature and the air temperature and relative humidity in a freestall barn.

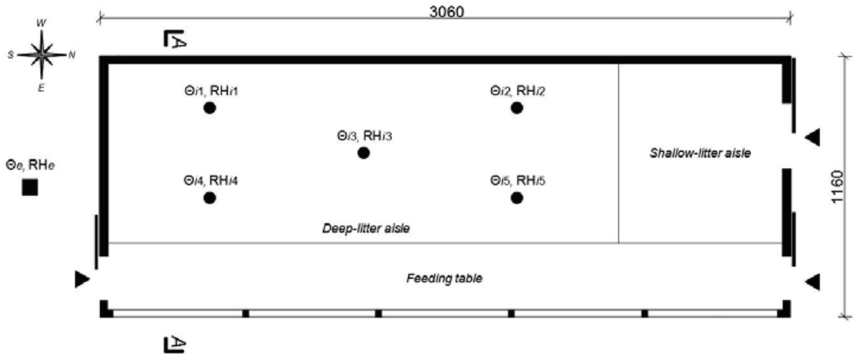
The scope of the research encompassed constant measurements of indoor and outdoor air temperature and relative humidity, litter temperature and monitoring the number of animals in the barn.

MATERIAL AND METHODS

The studies were conducted in a freestall barn with deep-litter bedding system, housing 50 dairy cows, located in the Holy Cross Voivodeship. The barn area amounts to 355 m^2 and is constructed of brick wall. Sidewalls are 29 cm thick and are made of ceramic hollow bricks, set on concrete foundations founded at 1.2 m below ground level. It has a 12 cm thick concrete floor situated on a 25 cm sand-gravel bed. Concrete floor is covered by a layer of wheat straw with a depth of 30 – 45 cm in summer and 45 – 60 cm in winter. The building is equipped with a natural ventilation system.

The studies were carried on in the period from 22 March 2014 to 22 March 2015. Throughout this period, indoor and outdoor air temperature and relative humidity were constantly monitored. Recorders USB Voltcraft DL-121TH were used to measure both parameters every 5 minutes. The location of measurement points is presented in Figure 1. Litter depth and temperature were also measured. Litter temperature was measured at 16 measurement points every 24 h using a probe Greisinger GSF 50 TF (Figure 2).

a)



b)

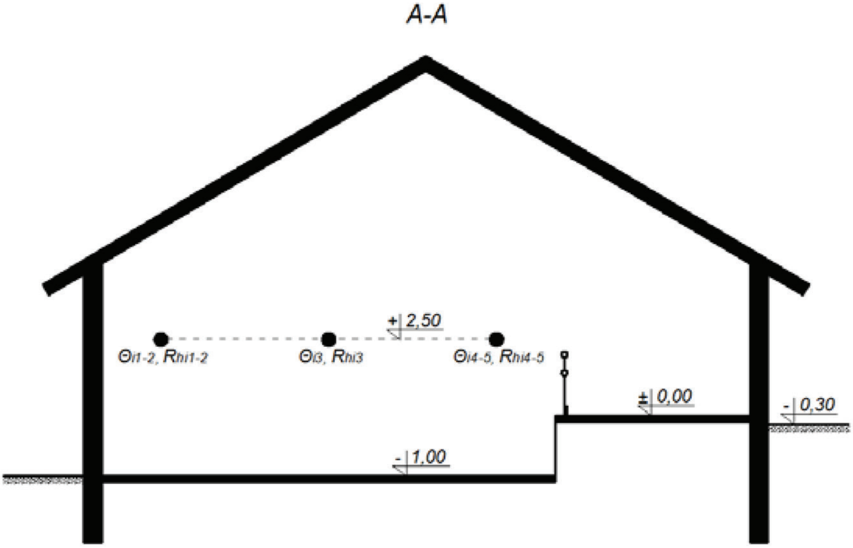


Figure 1. Location of measurement points for indoor ($\Theta_{i1\div5}$) and outdoor (Θ_e) air temperature and indoor ($RH_{i1\div5}$) and outdoor (RH_e) air relative humidity; a – projection, b – cross section

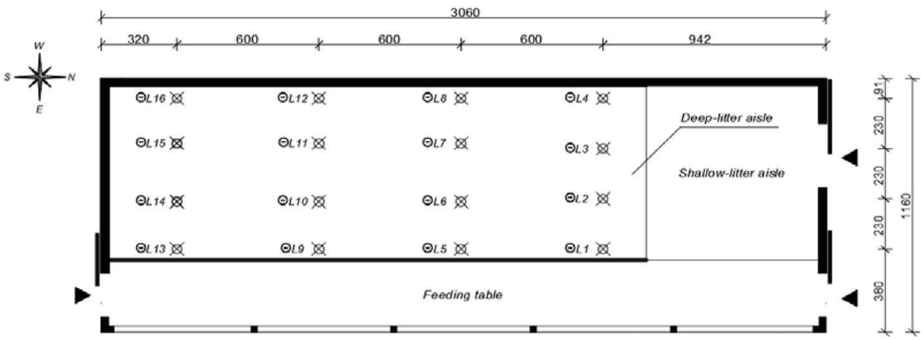


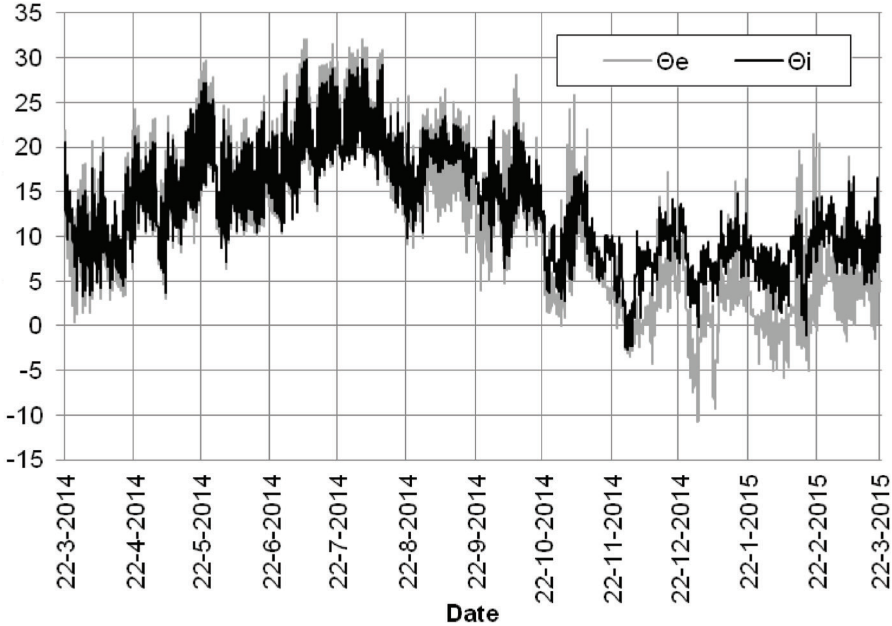
Figure 2. Location of measurement points for litter surface temperature ($\Theta_{L1\div20}$)

RESULTS AND ANALYSIS

The investigated building remained open throughout almost the whole study period. The barn was closed only twice in winter due to low outdoor temperature reaching – 10°C (from 5 to 12 December 2014 and from 6 to 9 January

2015). Such solution made the animals free to move between the barn and pasture and feed whenever they wanted.

a)



b)

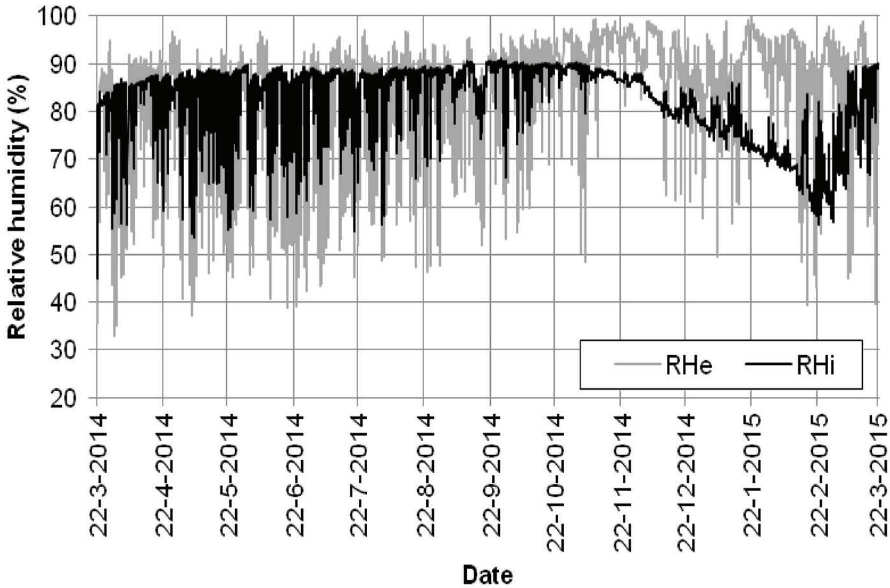


Figure 3. Air temperature and relative humidity traces: a) indoor (Θ_i) and outdoor (Θ_e) air temperature b) indoor (RH_i) and outdoor (RH_e) air relative humidity

Analysis of the results of indoor air temperature measurements (Figure 3) demonstrated its strong correlation with outdoor air temperature except for the periods when cows stayed in the barn. When cows were constantly present in the barn, litter surface temperature rose rapidly. These periods were characterized by the stabilization of indoor air temperature (7-10°C) and increase in indoor air relative humidity to 80%. Daily average values of indoor air relative humidity ranged from 55% to 80% in winter and from 55% to 90% in summer. Daily average values of indoor air temperature ranged from 17°C to 20°C in summer and from – 3°C do 11°C in winter.

When all cows stayed in the barn, a dynamic increase in liter temperature was observed. This phenomenon was particularly noticeable in winter when average litter temperature was 8°C. In this period, the lowest outdoor air temperature was – 10°C whereas indoor air temperature did not drop below 0°C. The results of litter temperature measurements are presented in Figure 4.

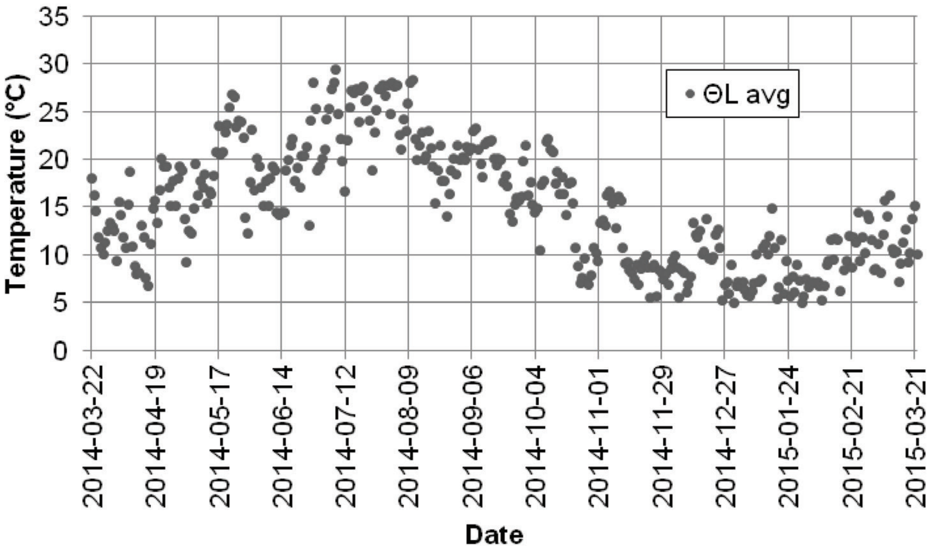


Figure 4. Average temperature of liter surface

Analysis of litter surface temperature showed its wide variability depending on the location of measurement point and on the number of animals present in the barn. Based on litter temperature distribution, two zones of resting area can be distinguished, namely the sidewall zone 1.5 m wide adjacent to the western outside wall of the barn and the inner zone encompassing the remaining part of the barn. The highest temperatures were noted in the inner zone and the lowest in the sidewall zone. Wide variability of liter temperature in these zones was noted when cows were in the barn (Figure 5a and 5d). This phenomenon should be linked with congregation of cows at the feeding table and in the inner zone. In those days, 45 cows were present in the barn on 22 March 2014 and 40 cows on 15 February 2015. Analysis of litter temperature in periods when cows were on pasture revealed that litter temperature was less variable throughout the whole resting area (Figure 5b and 5c). In periods, when animals stayed in the barn, litter temperature increased by ca. 5-8°C and differences in litter temperature throughout the whole resting area reached even 10°C depending on the location of the measurement point. In periods when the barn was empty or only a few cows were inside (up to 10 cows), litter temperature became more uniform throughout the whole barn surface and the differences did not exceed 3°C.

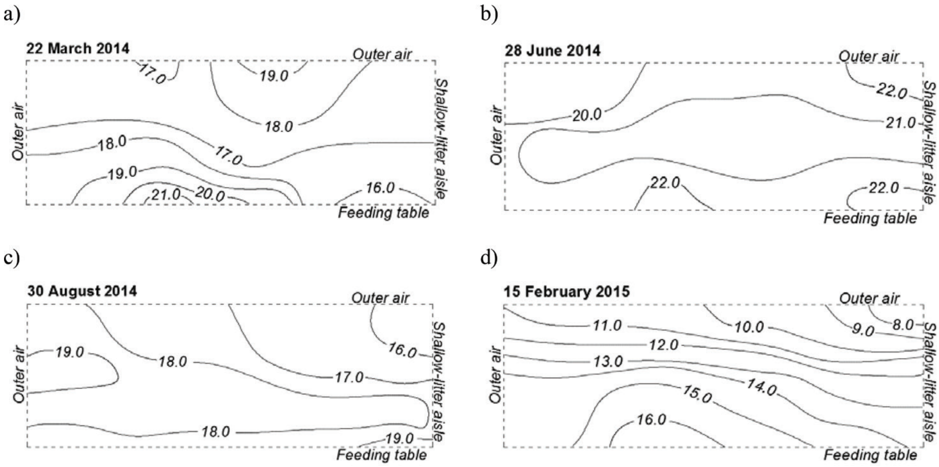


Figure 5. Deep-litter surface temperature in periods when cows were in the barn (a and d) and in periods when they were on pasture (b and c)

CONCLUSIONS

The present analysis of deep-liter surface temperature showed its strong relationship with indoor air temperature and with the number of cows staying in the barn. Due to the method of cow farming (constantly open barn, cows staying mostly on pasture), indoor air temperature and relative humidity were strongly dependent to outdoor conditions. Traces of indoor air temperature and relative humidity confirmed beneficial thermal conditions for dairy cattle in winter, while in summer, optimal temperature range.

The results of the studies demonstrate the effect of the number of animals staying in the barn on litter surface temperature. Periods when cows chose to stay in the barn were characterized by the existence of two zones of resting area significantly differing in thermal conditions, namely the zone adjacent to the feeding table and inner part of the barn and the zone 1.5 m wide adjacent to the western outside wall of the barn. Differences in litter temperature between these zones reached even 10°C. Variability of litter surface temperature was definitely reduced (up to 3°C) in periods when cows were outside the barn.

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