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HEAT STRESS RISK ALERT SYSTEM FOR DAIRY CATTLE IN SLOVENIA

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ABSTRACT

For the estimation of heat stress risk and modelling of prediction equations, temperature-humidity conditions were recorded on three dairy farms with different ventilation systems: natural ventilation (NV), fan ventilation during daytime (FVD) and fan ventilation during day and nighttime (FVDN). First data set was collected from April 1, 2010 to September 30, 2010 and the second from April 1, 2011 to September 30, 2011. On each farm hourly data of outdoor and barn air temperature and humidity were recorded. Results showed that in all barns the time of exposure to heat stress risk was longer compared to outdoor conditions. However, the maximum exposure to the heat stress risk conditions was reached in July 2010 and August 2011 when it was 19.1 and 18.5 hours for NV facility, 17.9 and 16.9 hours for FDV facility and 13.8 and 13.3 hours for FVDN system. Barn temperature-humidity index (THI) was estimated on the first data set. The model included the linear effect of ambient THI, month and hour of measurement. Validation of prediction equations was performed on the second data set, showing a correlation between true and estimated THI of 83.7 for NV, 82.7 for FVD and 89.4 for FVDN facility. Finally, system for prediction of dairy cow heat stress risk based on the most recent data from the nearest automatic meteorological station was incorporated into web page Govedo (www.govedo.si) to alert farmers on possible risk of heat stress.

Key words: cattle / dairy cows / heat stress / temperature-humidity index

1 INTRODUCTION

Selection mainly on higher milk production has brought dairy cows into the situation of higher susceptibility to heat stress. For that reason a reduction of negative thermal stress effects on reproduction and milk production during a summer months is an important issue. Cows with a similar body weight and different milk yield produce various amount of metabolic heat which needs to be dissipated into the environment (Purwanto *et al.*, 1990).

Heat stress may be caused by different environmental factors: temperature (T), relative humidity (RH), solar radiation, air movement and precipitation. The most important are T and RH which can be obtained from the nearest automatic meteorological station (Bohmanova *et al.*, 2007). For the estimation of the level of thermal stress, T and RH are combined into a temperature-humidity index (THI). With this index thermal stress related looses can be monitored and reduced with the installation of appropriate ventilation and cooling systems.

For Slovenian dairy cow facilities lack of fan ventilation and dairy cooling system is significant. Some barns are in the proximity of settlements and because of that they turn off fans during the nighttime for not bothering neighbours with noise caused by fans in operation. Breeding of dairy cows in relatively old barns with hay stored above the barn is still a prevailing practice. As grazing is practised on 37.5% of farms with Brown, 28.4% of farms with Holstein and 21.8% of farms with Simmental cattle breed, expectations that global warming will have an important impact on dairy cattle breeding in Slovenia are reasonable (Perpar *et al.*, 2010; Nardone *et al.*, 2010). However, milk yield increase, e.g. 22%

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in the last ten years for Brown cows in Slovenia (Perpar *et al.*, 2010), caused higher susceptibility of dairy cow to heat stress.

The objectives of this study were to estimate the duration of heat stress risk for dairy cows in different facilities and to develop equations for barn THI estimation, for three most frequent barn ventilation systems in Slovenia: natural ventilation (NV), fan ventilation during daytime (FVD) and fan ventilation during day and nighttime (FVDN).

2 MATERIAL AND METHODS

Through the warm season (April 1 – September 30) of 2010 and 2011, climatic conditions were monitored hourly on three dairy farms with different ventilation systems: NV, FVD and FDN. Measurements were recorded with T and RH data logger (H-Button 23). The accuracy of measurements was set to 0.1 °C for T and 1% for RH. To minimize the effect of solar radiation, data loggers were installed in a shelter about 2 meters above the ground. The obtained T and RH records were used to calculate the THI with the Oklahoma Mesonet cattle heat stress index equation (National Research Council, 1971).

$$THI = (1.8 \cdot T + 32) - (0.55 - 0.0055 \cdot RH) \cdot (1.8 \cdot T - 26) \quad (1)$$

According to the THI five comfort zones were defined: < 72 – no stress, 72–78 – mild stress, 78–89 – severe stress, 89–98 – very severe stress and > 98 – dead cows (Moran, 2005). Before the prediction equation modelling was performed, records with barn THI lower than 66 were discarded. Model for the estimation of barn THI (y_{ijk}) included i-th month class effect (M_i; i = 1 to 6), j-th hour class effect (H_j; j = 1 to 24), linear regression effect of outdoor THI (thi_{ijk}) and residual (e_{ijk}).

$$y_{ijk} = \mu + M_i + H_j + b \cdot thi_{ijk} + e_{ijk}, \quad (2)$$

where μ is the intercept and b represents the change in indoor THI per one unit change in outdoor THI. Data between April 1, 2010 and September 30, 2010 were used as a training set, whereas prediction accuracy was tested on a data obtained between April 1, 2011 and September 30, 2011.

3 RESULTS

The exposure to heat stress risk in barn with NV was considerably longer compared to outdoor conditions. In both years (2010 and 2011) there were three months over 12 hours exposure to mild heat stress risk in barn, reaching the top in July 2010 with 19.1 and 18.5 hours in August 2011 (Fig. 1). On the other hand heat stress conditions existed outside the barn for 8.4 and 8.8 hours in July 2010 and August 2011, respectively. Differences in time of exposure to severe heat stress risk between outdoor and indoor conditions were smaller.

In facility with FVD animals were on an average day exposed to a heat stress risk for 17.9 and 16.9 hours in July 2010 and August 2011, respectively (Fig. 2). Outdoor conditions at that time were more favourable, reaching 8.5 hours in July 2010 and 7.7 hours of exposure to heat stress risk in August 2011. At that time also the longest average time of severe heat stress risk occurred.

Maximum average time of exposure to heat stress risk in facility with FVDN was reached in June 2010 with 13.8 hours and in August 2011 with 13.3 hours (Fig. 3). The duration of heat stress risk conditions outside the barn was shorter, reaching 9.6 and 9 hours in June 2010 and August 2011, respectively. Average time of heat stress risk exceeded 12 hours per day only in one month of each year.

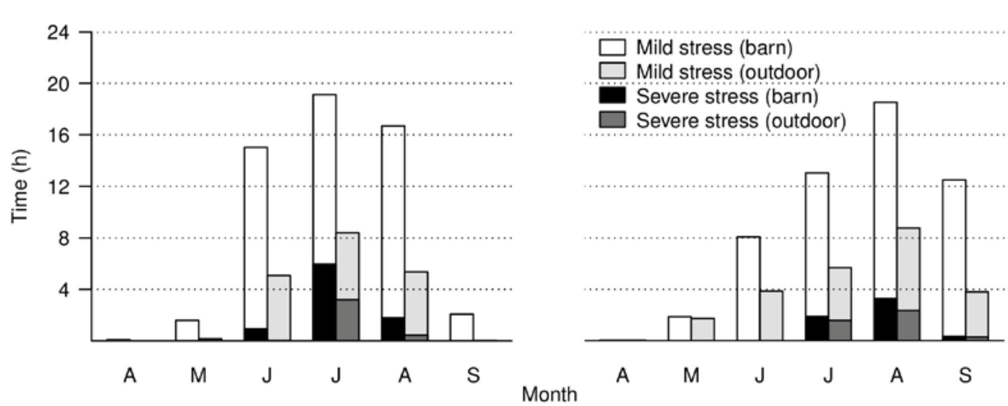

Figure 1: *Average time of exposure to mild and severe heat stress risk for dairy cattle in barn with natural ventilation system and outside the barn between April and September, 2010 (left) and 2011 (right)*

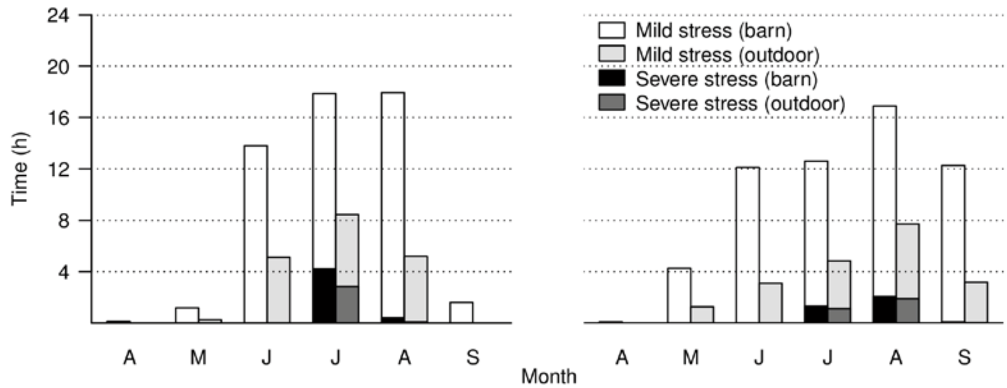

Figure 2: *Average time of exposure to mild and severe heat stress risk for dairy cattle in barn with fan ventilation system in operation during the daytime and outside the barn between April and September, 2010 (left) and 2011 (right)*

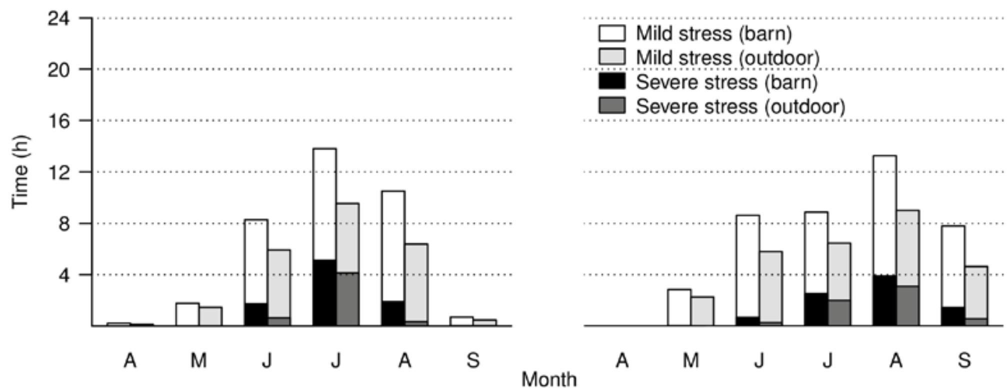

Figure 3: *Average time of exposure to mild and severe heat stress risk for dairy cattle in barn with fan ventilation system in operation during day and nighttime and outside the barn between April and September, 2010 (left) and 2011 (right)*

Coefficients of determination for barn THI estimation were 0.82, 0.81 and 0.87 in facility with NV, FVD and FVDN, respectively. Correlations between true THI and estimated THI ranged from 82.7 to 89.4 (Table 1). In barn with NV estimated THI was overestimated for 1.00 and in barn with FVD for 0.52, whereas in barn with FVDN a slight underestimation (0.06) was noticed. The biggest root of mean square error, which accounts for the variance and bias of the estimator, was noticed for NV system (2.01) then the system with FVDN (1.77) and the smallest for the FVD (1.67).

Table 1: *Accuracy (r), bias and root mean square error (RMSE) of estimated barn temperature-humidity index for year 2011 with coefficients obtained from measurements in year 2010*

	Natural ventilation	Daytime fan ventilation	Day and nighttime fan ventilation
r	83.7	82.7	89.4
Bias	−1.00	−0.52	0.06
RMSE	2.01	1.67	1.77

4 DISCUSSION

Mild heat stress risk was recognized during the whole observation period (April to September), whereas severe heat stress risk conditions were observed from June to September. These findings are relatively similar to the results obtained from tie-stall barn in Kahramanmaras, Turkey, where mild heat stress risk conditions were detected between May and October (Akyuz *et al.*, 2010). The most effective in reduction of heat stress risk was FVDN facility. In this system differences in exposure to heat stress between barn and outside conditions were on average longer in barn for 4.3 hours in July 2010 and August 2011. This result is still not promising compared to the study of Stovell *et al.* (2001) where indoor thermal conditions were reported to closely track those outdoors for tunnel ventilation system and natural ventilation system with supplemental cooling fans. Exposure to heat stress risk in NV and FVD system were similar. In July 2010 cows experienced the heat stress risk in NV barn for 10.7 hours and in August 2011 for 9.8 hours longer compared to housing outdoor in a shaded place. The overall highest difference between the indoor and outdoor average monthly exposure to heat stress risk of 12.8 hours was observed in August 2010 for FVD facility, whereas the difference reached 9.2 hours in August 2011. However, nighttime ventilation reduces the difference between the barn THI and the outside THI, but there are also other facilities designed to improve the cow welfare and reduce the heat stress risk more effectively. One of the options is low profile cross-ventilated freestall barn where air enters the barn through evaporative cooling pads and is exhausted on the opposite side (Smith *et al.*, 2007). Evaporative cooling is using the energy from the air to evaporate water reducing the air T and increasing the RH, however it is more effective in arid climates (Brouk *et al.*, 2003).

Correlations between measured THI and estimates obtained from the equations were high. The highest correlation was found for the FVDN facility, which is not surprising as there the barn air was exchanging with the outside air all the time. Monthly correlations reported by Erbez *et al.* (2010) for the free stall barn with permanently opened sides were even higher and were starting from 0.84. The equations for the estimation of barn THI were incorporated into the web application for heat stress risk prediction based on the data from the nearest automatic meteorological station. All dairy cow breeders who are members of Slovenian milk recording system can access the application from the web page (www.govedo.si).

5 CONCLUSION

Temperature-humidity conditions distinguish between different ventilation systems. For that reason a tool for the estimation of barn THI based on the data obtained from the nearest automatic meteorological station to alert farmers in case of a heat stress risk was developed. The application is freely available on the web page (www.govedo.si) to all farmers included in the dairy milk recording system in Slovenia.

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