sciendo

DOI: 10.2478/ata-2022-0015

Acta Technologica Agriculturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2022, pp. 92–96

ANALYSIS OF SELECTED DATA FROM ROBOTIC MILKING REGARDING TO HEAT STRESS OF DAIRY COWS

Štefan BOĎO[1], Gabriel LÜTTMERDING[1]*, Roman GÁLIK[1], Petr KUNC[2], Ivana KNÍŽKOVÁ[2], Gürkan Alp Kagan GÜRDIL[3]

[1]Slovak University of Agriculture in Nitra, Slovakia
[2]Institute of Animal Science, Praha Uhříněves, Czech Republic
[3]Ondokuz Mayis University, Samsun, Turkey

The paper presented is dedicated to investigation of the temperature-humidity index (THI) and its impacts on the performance parameters of dairy cattle. These parameters were recorded at four farms in the central Slovakia; the experiments took place three years. These parameters comprised milking time, time spent in the milking box, and connection time. The THI was calculated according to the standard formula and individual periods were established on the basis of achieved THI values. The results showed that the milking time and the time spent in the milking box were not reduced when the THI ranged from 68 to 71, with a daily milk yield of 28.96 kg. If the THI exceeded 72, the milking time and the time spent in the milking box were shortened, which was statistically confirmed. However, even with a daily milk yield of 31.27 kg, a reduction in the milking time and time spent in the milking box was reduced. This was caused by the THI higher than 68, which was also statistically confirmed. Based on the results obtained, the dairy cows respond to heat stress by reducing the milking time and reducing time spent in the milking box.

Keywords: temperature-humidity index; milking time; time spent in milking box; connection time

Utilization of automatic milking systems (AMS) at dairy farms came to the forefront in the last two decades. The biggest advantage of AMS includes a reduction of a workload of the farm staff and the possibility of milking more than twice a day without higher labour costs (Williams, 2019). It is very important to emphasize the fact that the AMS does not only include an in-house robotic milking, but also represents a completely new management at dairy farms (Svennersten-Sjaunja and Pettersson, 2007; Hulsen and Rodenburg, 2011). The AMS allows collection of basic data from individual serial electric buses connected to the AMS milking equipment. Digitalization of collected data helps the management to track individual data. This includes a wide range of data of dairy cows, which might be useful in optimization of individual dairy farming processes (Hulsen and Rodenburg, 2011). Yet, the anticipated positive effects of the AMS employment may be disturbed by inappropriate microclimatic and macroclimatic conditions (Bava et al., 2012). Particularly, the heat stress significantly affects the welfare of dairy cows; the negative impacts of heat stress are usually manifested as reduced milk yield, reduced feed intake, increased water consumption, impaired reproductive performance, etc. (Dahl, Tao and Monteiro, 2016; Herbut, Angrecka and Walczak, 2018; Sejian et al., 2018; Saha et al., 2019). The temperature humidity index (THI) is frequently used for the purposes of description of heat load. As it takes into account the combined impacts of the air temperature, relative humidity, and water intake, THI represents a very important indicator of the barn environment quality (Herbut, Angrecka and Walczak, 2018; Gantner et al., 2017; Lendelová et al., 2017; Habeeb, Gad and Atta, 2018; Peng et al., 2019; Némethová et al., 2020; Vaculík et al., 2021). Although this model does not take into consideration other environmental factors, i.e., air velocity or solar radiation intensity, the THI model is still considered to be an excellent indicator of stressful climatic conditions (Herbut, Angrecka and Walczak, 2018; Habeeb, Gad and Atta, 2018). A high THI negatively influences the milk yield of dairy cows (Herbut, Angrecka and Walczak, 2018; Gantner et al., 2017; Habeeb, Gad and Atta, 2018; Brouček et al., 2019) and a THI value exceeding 72 is considered a critical value (Bava et al., 2012). Furthermore, a decrease in the milk yield was observed two days prior to reaching the THI limit values (Spiers et al., 2004). Moreover, Bernabucci et al. (2014) observed that the daily milk production starts to decrease when THI reaches values of 65–76. A THI value of 68 has adverse impacts on the organism of dairy cattle (Collier, Dahl and Vanbaale, 2006). Additionally, according to Zimbelman et al. (2009), the THI limit value for dairy cows producing more than 35 kg of milk per day is 68.

The study presented was aimed at investigation of the impacts of THI on selected AMS parameters. If an increased THI value affects the performance of dairy cows, it is very likely that the increased THI also affects the milking time, time spent in box, etc. In addition to other indicators, Ji et al. (2020) also addressed the following: the impact of heat stress and subsequent reactions of animals on daily milk

Contact address: Gabriel Lüttmerding, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, e-mail: xluttmerding@uniag.sk

yield; milking time; milking frequency; duration of milking; and milking speed. The authors did not find any significant correlation between heat stress and animal behaviour during milking. If the productivity of high-productive dairy cows decreases, it is very likely that the time spent in the milking box will also decrease.

Therefore, this paper presents acquired experimental data from AMS and subjects them to an analysis. These results follow the research by Gálik et al. (2021), further elaborating new knowledge. The study focuses on the analysis of the impacts of THI on following parameters: milking time (s), time spent in the milking box (s) and connection time to milking set (s).

Material and methods

Farms and animals

The experimental measurements were performed at four dairy farms located in the Slovak Republic (A, B, C, D). The Holstein breed was selected for the measurements. The cattle subjected to experiments included cows after the first calving, as well as older ones. Dairy cows were kept in a loose housing with a cubicle beds and bedding. There were provided a free access to all the milking robots. All dairy cows were fed the same total mixed ration (TMR). The Lely Astronaut A3 and A4 were used at each farm (Lely, Maassluis, the Netherlands). Table 1 provides information in detail on the observed four farms (Gálik et al., 2021).

Data collection

The experiments were conducted for a period of three years. The monitored parameters included: milking time (s), time spent in the milking box (*s*) and connection time of the milking set (*s*). These data were extracted from AMS reports of selected farms.

The air temperature and relative humidity were continuously recorded to calculate the THI values. These parameters were measured using Comet COMMETER D3120 recorders (COMET SYSTEM, s.r.o, Roznov pod Radhostem, the Czech Republic). The access of cattle to these measuring devices was prevented.

The THI values were calculated on the basis of recorded values of air temperature and relative humidity. The following formula was used (Bilby, 2014):

$$THI = Tdb - \left[0.55 - \left(0.55 \cdot \frac{RH}{100}\right)\right] \cdot (Tdb - 58)$$

where: *Tdb* – air temperature (F); *RH* – relative humidity (%)

The THI values were classified into zones on the basis provided by Herbut, Angrecka and Walczak (2018): 1st zone (THI 64–67) – stress-free zone; 2nd zone (THI 68–71) – very mild stress zone; 3rd zone (THI 72–79) – moderate stress zone; 4th zone (THI 80–89) – severe stress zone; 5th zone (THI 90–98) – extreme stress zone; 6th zone (THI 99–104) – death zone.

Data analysis

The data from the summer period (June, July, August) of each year of measurements were used for the evaluation. Each farm was assessed separately. The data monitoring started three days prior to reaching the 2nd zone of THI (68–71). This was followed by monitoring of data from days when THI rose above 72 and the data from the day after THI fell below 68.

Table 2 illustrates the specifics of the zones of evaluation, which were used for the graphs description. The following parameters were evaluated: the impact of THI on the milking time (s), the impact of THI on the time spent in the milking box (s) and the impact of THI on the connection time of the milking set (s) (Gálik et al., 2021).

Table 2 Zones of evaluation

Zone	Zone description
1st	three days prior to reaching of the very mild stress zone
2nd	very mild stress (68–71)
3rd	moderate stress zone (72–79)
4th	the day after the decrease of THI under 68

Statistical analysis

The data from the farms were imported into Microsoft Office Excel (Microsoft, Redmond, the United States of America). For the purposes of plotting the graphs, a statistical software Statistica 12 (TIBCO, Palo Alto, the United States of America) was employed. Resulting data were given as means ±SD (standard deviation). The one-way ANOVA was used, followed by the Tukey's *post hoc* test. The 95% confidence interval (p <0.05) was selected.

Results and discussion

Table 3 provides the details on the days with the THI values exceeding 68. The majority of days with such conditions were recorded in the first year of measurements. Most days with the THI values higher than 72–79 were recorded at

Table 1 Information on dairy farms

Farm	AMS type	Number of AMS at the farm	Number of dairy cows	Average annual performance per dairy cow (kg)
A	Lely Astronaut A3	1	58	6517.00
B	Lely Astronaut A4	4	288	8717.56
C	Lely Astronaut A4	4	295	7500.00
D	Lely Astronaut A4	4	303	8710.25

Table 3 Days with the highest THI values

Farm	Year	Days with THI in range of 68–71	Days with THI in range of 72–79
A	1	22	31
	2	19	12
	3	25	16
B	1	26	12
	2	17	2
	3	16	7
C	1	26	29
	2	18	12
D	1	26	4
	2	12	2
	3	10	3

Table 4 Descriptive statistics of data acquired from all farms

Farm	Parameter	Average	Minimum	Maximum	Standard deviation
A	milking time (s)	358.70	352.51	364.88	41.93
	time in box (s)	490.13	482.46	497.80	52.02
	connection time (s)	39.64	38.90	40.39	5.04
	THI	70.06	69.48	70.64	3.94
B	milking time (s)	285.64	283.58	283.58	24.83
	time in box (s)	411.72	409.41	414.02	27.81
	connection time (s)	41.93	41.46	42.40	5.67
	THI	68.04	67.74	68.34	3.58
C	milking time (s)	283.90	281.55	286.25	27.22
	time in box (s)	437.73	435.02	440.44	31.39
	connection time (s)	40.67	40.12	41.22	6.35
	THI	69.60	69.26	69.94	3.95
D	milking time (s)	280.78	278.57	283.00	24.68
	time in box (s)	415.51	413.21	417.82	25.67
	connection time (s)	45.43	44.90	45.97	5.99
	THI	67.55	67.25	67.85	3.36

the farm A. In case of days with THI values exceeding 68, the most were recorded at the farm C, and this was also recorded during the first year of measurements (Gálik et al., 2021).

The farm A had provided only one milking robot. Three milking robots were provided at the farms B, C and D. Only the data from the summer period were subjected to statistical processing. The impact of THI on individual parameters was statistically evaluated.

The results of descriptive statistics of each farm were already discussed by Gálik et al. (2021). All in all, it was observed that the farm D showed the highest average value of the milk yield per cow per day (31.27 kg). On the other hand, the lowest average value of the milk yield per cow per day was showed by the farm A. The highest value of THI 70.06 was recorded at the farm A.

The results of descriptive statistics of the THI and three selected parameters from all farms are shown in Table 4.

Considering the impacts of THI on the connection time of the milking set at the farm D (Fig. 1), with the highest milk yield, there was not observed any significant demonstrable value that would cause a major influence. This is true for the rest of analysed farms as well.

Figure 2 shows a decrease in milking time at the farm D. Statistically significant difference (p <0.05) was observed between the values of the 1st and 2nd zone of evaluation (8.3 seconds), as well as between the 1st and 3rd zone of evaluation (18 seconds). The other differences were statistically insignificant.

Figure 3 shows a decrease in time spent in the milking box at the farm D. Statistically significant difference (p <0.05) was observed between the values of the 1st and 2nd zone

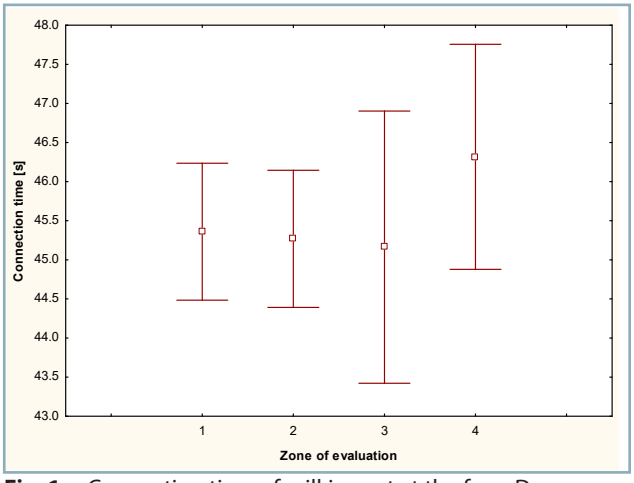


Fig. 1 Connection time of milking set at the farm D

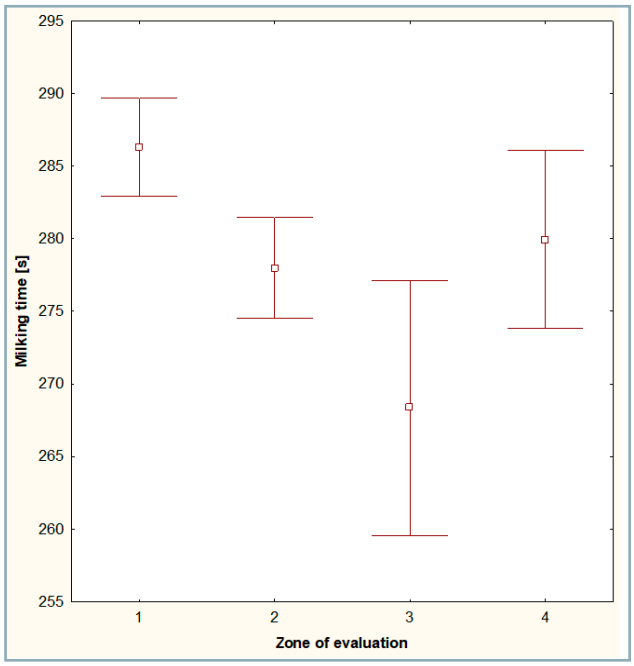


Fig. 2 Milking time at the farm D

of evaluation (8.2 seconds), as well as between the 1st and 3rd zone of evaluation (19.4 seconds). The other differences were statistically insignificant.

The experimental results indicate that both the milking time and the time spent in the milking box can be significantly lower when a dairy cow is under the heat stress, which might be caused by the fact that cattle is trying to dispose of the accumulated heat in the form of milk. This complies with observations made by Kadzere et al. (2002), who came to conclusion that the metabolic heat output increases with the amount of milk and the cow thus attempts to get rid of this metabolic heat. The paper presented follows up on the conclusions made by Gálik et al. (2021). These conclusions confirm the effect of THI not only on the increased milking speed, but also on the reduced time spent in the milking box when the dairy cows are under the heat stress. If the THI exceeds the value of 68 (2nd zone of evaluation) or becomes greater than 72 (3rd zone of evaluation), the results show

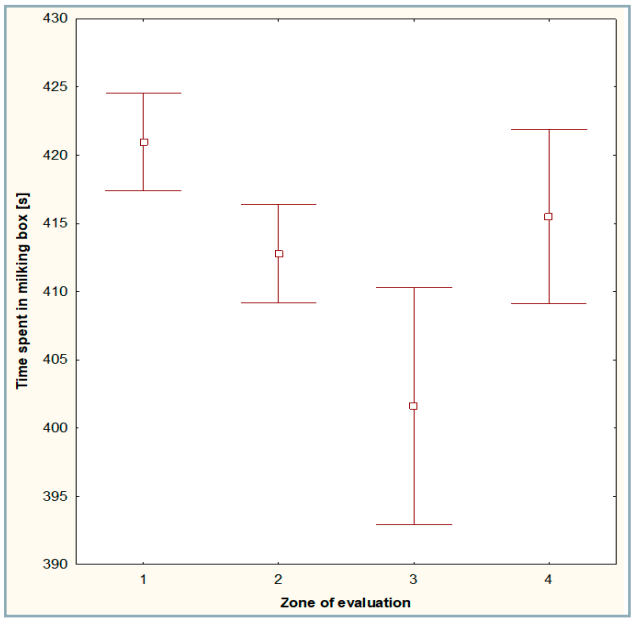


Fig. 3 Time spent in milking box at the farm D

a statistically significant reduced time spent in the milking box in contrast to the 1st zone of evaluation, which was also statistically confirmed. When the THI value dropped below 68, the time spent in the milking box did not change back to its original state even after 24 hours. However, this value was not statistically significant.

Conclusion

In spite of the fact that the animals at observed farms were provided the same feed ration, appropriate amount of drinking water and identical level of animal welfare for the entire duration of experiments, the results point to conclusion that the decreased values of milking time and the time spent in the milking box were related to the THI. The results showed that there was found a positive effect on reducing the milking time or the time spent in the milking box at THI value higher than 72. These results also show a statistically significant decrease in both the milking time and the time spent in the milking box even in dairy cows with higher performance. As soon as the THI value dropped back to 68, both values of the milking time and time spent in the box increased, but these values were not statistically significant.

Acknowledgments

This publication was supported by the Operational Programme Integrated Infrastructure within the project: Sustainable smart farming systems taking into account the future challenges 313011W112, co-financed by the European Regional Development Fund, and also supported by the Ministry of Agriculture of the Czech Republic, institutional support MZE-RO0718.

References

BAVA, L. – TAMBURINI, A. – PENATI, C. – RIVA, E. – MATTACHINI, G. – PROVOLO, G. – SANDRUCCI, A. 2012. Effects of feeding frequency

and environmental conditions on dry matter intake, milk yield and behaviour of dairy cows milked in conventional or automatic milking systems. In Italian Journal of Animal Science, vol. 11, no. 3, pp. e42.

BERNABUCCI, U. – BIFFANI, S. – BUGGIOTTI, L. – VITALI, A. – LACETERA, N. – NARDONE, A. 2014. The effects of heat stress in Italian Holstein dairy cattle. In Journal of Dairy Science, vol. 97, no. 1, pp. 471–486.

BILBY, T. 2014. How do I determine?: How do I calculate temperature-humidity index (THI)? Available at: https://www.progressivedairy.com/topics/herd-health/how-do-i-determine-how-do-i-calculate-temperature-humidity-index-thi.

BROUČEK, J. – RYBA, S. – DIANOVÁ, M. – UHRINČAŤ, M. – ŠOCH, M. – ŠÍSTKOVÁ, M. – MALÁ, G. – NOVÁK, P. 2019. Effect of evaporative cooling and altitude on dairy cows milk efficiency in lowlands. In International Journal of Biometeorology, vol. 64, no. 3, pp. 433–444.

COLLIER, R. J. – DAHL, G. E. – VANBAALE, M. J. 2006. Major advances associated with environmental effects on dairy cattle. In Journal of Dairy Science, vol. 89, no. 4, pp. 1244–1253.

DAHL, G. E. – TAO, S. – MONTEIRO, A. P. A. 2016. Effects of late-gestation heat stress on immunity and performance of calves. In Journal of Dairy Science, vol. 99, no. 4, pp. 3193–3198.

GANTNER, V. – BOBIC, T. – GANTNER, R. – GREGIC, M. – KUTEROVAC, K. – NOVAKOVIC, J. – POTOCNIK, K. 2017. Differences in response to heat stress due to production level and breed of dairy cows. In International Journal of Biometeorology, vol. 61, no. 9, pp. 1675–1685.

GÁLIK, R. – LÜTTMERDING, G. – BOĎO, Š. – KNÍŽKOVÁ, I. – KUNC, P. 2021. Impact of heat stress on selected parameters of robotic milking. In Animals, vol. 11, no. 11, article no. 3114.

HABEEB, A. – GAD, A. E. – ATTA, M. A. 2018. Temperature-humidity indices as indicators to heat stress of climatic conditions with relation to production and reproduction of farm animals. In International Journal of Biotechnology and Recent Advances, vol. 1, no. 1, pp. 35–50.

HERBUT, P. – ANGRECKA, S. – WALCZAK, J. 2018. Environmental parameters to assessing of heat stress in dairy cattle – a review. In International Journal of Biometeorology, vol. 62, no. 12, pp. 2089–2097.

HULSEN, J. – RODENBURG, J. 2011. Robotic milking. Zuthpen : Roodbont Publishers, 52 pp. ISBN 9789087400439.

JI, B. – BANHAZI, T. T. – GHAHRAMANI, A. – BOWTELL, L. A. – WANG, C. – LI, B. 2020. Modelling of heat stress in a robotic dairy farm. Part 3: Rumination and milking performance. In Biosystems Engineering, vol. 199, pp. 58–72.

KADZERE, C. T. – MURPHY, M. – SILANIKOVE, N. – MALTZ, E. 2002. Heat stress in lactating dairy cows: a review. In Livestock Production Science, vol. 77, no. 1, pp. 59–91.

LENDELOVÁ, J. – KARANDUŠOVSKÁ, I. – ŽITŇÁK, M. – BOĎO, Š. – MIHINA, Š. 2017. Effect of climatic conditions on differences in thermo-technical properties of organic bedding in laboratory testing. In Acta Technologica Agriculturae, vol. 20, no. 1, pp. 1–6.

NÉMETHOVÁ, M. – LENDELOVÁ, J. – ŠRANKOVÁ, V. – ŽITŇÁK, M. – BOTTO, Ľ. 2020. Verification of thermo-technical characteristics of selected floor constructions for dairy cows (pilot study). In Acta Technologica Agriculturae, vol. 23, no. 2, pp. 87–91.

PENG, D. – CHEN, S. – LI, G. – CHEN, J. – WANG, J. – GU, X. 2019. Infrared thermography measured body surface temperature and its relationship with rectal temperature in dairy cows under different temperature-humidity indexes. In International Journal of Biometeorology, vol. 63, no. 3, pp. 327–336.

SAHA, S. – AMALFITANO, N. – STURARO, E. – SCHIAVON, S. – TAGLIAPIETRA, F. – BITTANTE, G. – CARAFA, I. – FRANCIOSI, E. – GALLO, L. 2019. Effects of summer transhumance of dairy cows to alpine pastures on body condition, milk yield and composition, and cheese making efficiency. In Animals, vol. 9, no. 4, article no. 192.

SEJIAN, V. – BHATTA, R. – GAUGHAN, J. B. – DUNSHEA, F. R. – LACETERA, N. 2018. Review: adaptation of animals to heat stress. In Animal, vol. 12, pp. 431–444.

SPIERS, D. – SPAIN, J. – SAMPSON, J. – RHOADS, R. 2004. Use of physiological parameters to predict milk yield and feed intake in heat-stressed dairy cows. In Journal of Thermal Biology, vol. 29, no. 7, pp. 759–764.

SVENNERSTEN-SJAUNJA, K. M. – PETTERSSON, G. 2007. Pros and cons automatic milking in Europe. In Journal of Animal Science, vol. 86, pp. 37–46.

VACULÍK, P. – JEHLIČKA, T. – KAŽIMÍROVÁ, V. – SMEJTKOVÁ, A. 2021. Water consumption in the automatic milking systems. In Acta Technologica Agriculturae, vol. 24, no. 3, pp. 136–142.

WILLIAMS, D. 2019. Welfare implications for dairy cattle of modern technological advances: (I) robotic milking. In Journal of Dairy and Veterinary Sciences, vol. 9, no. 5, article no. 555772.

ZIMBELMAN, R. B. – RHOADS, R. P. – RHOADS, M. L. – DUFF, G. C. – BAUMGARD, L. H. – COLLIER, R. J. 2009. A re-evaluation of the impact of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. In Proceedings of Southwest Nutrition and Management Conference, Tempe AZ, University of Arizona, Tuscon, pp. 158–168.