INDOOR ENVIRONMENT IN MILKING PARLOR AND COWSHED DURING THE MILKING PROCESS

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Abstract. The aim of this work is to evaluate the results of measurements of the main microclimatic parameters (temperature, relative humidity, CO_2 concentration, illumination and noise) in the cowsheds and in the milking parlors during the milking process and compare the measured values with the appropriate standard values. The purpose of the measurement is to determine the changes of the microclimatic parameters to which dairy cows are exposed during the passage from the barn to the milking parlor and back to the stables. The basic environmental parameters affect the welfare of dairy cows and thereby the quality of milk. These parameters were measured in the new tandem parlor for 2 x 4 cows built in 1997 for modernized cowshed for 130 dairy cows. It was also measured in the rotary milking parlor for 24 cows which was built in 2001 for a new barn with capacity 220 cows which was built in 2002. The measurements were carried out during the winter and summer period.

Keywords: CO_2 concentration, illumination, measurement, noise, relative humidity, temperature, THI.

1. Introduction

The aim of this paper is to show the results of the measurement of the main microclimatic parameters (temperature, relative humidity, CO_2 concentration, illumination and noise) in the cowsheds and in the parlors during the milking process and compare the obtained results with the appropriate standard values.

Environmental conditions are determined by characteristic factors, especially by physical factors (temperature, relative humidity, illumination, noise etc.), chemical factors (concentration of CO_2, etc.) and biological factors [1]. Thermal state of the indoor environment is characterized by temperature and humidity. As a consequence of the analysis of a thermal environment is a formation of optimal conditions for the human and animal organism [2; 3]. The required optimal temperature in the cowshed and in the milking parlor in both winter and summer period is shown in Table 1 [4; 5].

Table 1

Required internal temperature in the cowshed and milking parlor in winter and summer

Location	Minimum	Optimum	Maximum
	Winter period		
Cowshed	2 ºC	4-10 ºC	-
Milking parlor	10 ºC	14-16 ºC	-
	Summer period		
Cowshed	-	14-22 ºC	26 ºC
Milking parlor	-	14-22 ºC	26 ºC

A thermal state of the indoor environment is also influenced by relative humidity. High water vapor content in the air reduces the possibility of cooling the body of man or animal by evaporation. It can cause heat stress already at a relatively low temperature of indoor environment [2]. Relative humidity should be ideal in the range of 40-80 % [6]. The maximum allowable value according to the Czech standard is 85 % [5]. Long-term exposure of relative humidity above 85 % adversely affects the organism and apparatus and could damage wooden elements of the buildings [2; 7].

The effect of combinations of temperature and humidity is included in the temperature–humidity index (THI). THI value below 70 is considered as comfort for cattle. The THI in the range of 70-78 is considered as stressful and values higher than 78 cause extreme suffering (organism is enable to maintain the thermoregulatory mechanisms or normal body temperature) [2; 8].

Hygienic comfort of the indoor environment is characterized by concentration of noxious gases and dust pollution. The most common noxious gases in the stables are carbon dioxide, hydrogen sulfide and ammonia [4; 9]. Carbon dioxide (CO_2) is normally in concentrations of 0.1 to 0.3 % (about ten times more than in the open atmosphere). In very poorly ventilated buildings it can reach

concentrations from 0.4 to 0.6 %. The main importance of concentration of CO_2 is in the indication of the quality of interior air, and thus the effectiveness of the ventilation system [3; 9]. The maximum allowable value of concentration of CO_2 according to the Czech standard is 0.25 % [5].

Visual comfort of the indoor environment is characterized by intensity of illumination. Illumination is divided into physiological and working. Physiological illumination is needed primarily for biological well-being of the organism. Working illumination creates favorable conditions for safe execution of work and for the assessment of environmental hygiene [3; 6; 10]. For cowsheds both are required – the physiological and working illumination at level of 60 lx. For milking parlors the working illumination at level of 200 lx is required [10; 11].

Acoustic comfort of the indoor environment is characterized by the sound pressure level. Noise in agricultural buildings is variable and depends mainly on the technological equipment (stable mechanical equipment, HVAC equipment), object size, and the number of animals in the stable [1]. Noise is harmful especially during the long influence. The sound pressure level up to 65 dB is harmless for dairy cows. However, the values above 85 dB are considered as harmful [10].

Indoor environmental condition is just one of the many factors that influence dairy production. Many scientific papers deal with dairy production [12; 13; 14].

2. Materials and methods

We measured in two farms (at the same time in the cowshed and milking parlor) during the milking process during the winter and summer periods.

- **FARM A** – On this farm there is a rotary milking parlor for 24 cows which was built in 2001 for a new barn with capacity 220 cows which was built in 2002. The construction of the cowshed is lightweight with timber elements. Milking on this farm is done in the morning (3:00 – 9:30) and in the afternoon (15:00-21:00).
- **FARM B** – On this farm there is a new tandem parlor for 2 x 4 cows built in 1997 for modernized cowshed for 120 dairy cows. This cowshed is a robust brick construction with thick external walls. Milking on this farm is done twice in the morning (4:30-11:00) and once in the afternoon (15:30-18:30).

The concentration of CO_2 was measured by the sensor FY A600 with operative range 0-0.5 % and accuracy ± 0.01 %. The intensity of illumination was measured by the sensor A613-VL with operative range 0-20,000 lx and accuracy ± 0.01 % of the measured values. The sound pressure level was measured with the sensor UNITEST 93411 with operative range 35-135 dB and accuracy ± 0.1 dB. All data were measured continuously and stored at intervals of three minutes to the measuring instrument ALMEMO 2590–9 during the measurement (approximately 120 minutes). In the milking parlor the measuring apparatus was situated in the space of the worker. In the cowshed the measuring assembly was located at different places during the measurement. The data about internal temperature and relative humidity were measured continuously and stored at intervals of ten minutes to DATA LOGGER ZTH65 with temperature operative range -30-80 ºC with accuracy ± 0.4 ºC and operative range of relative humidity 5-95 % with accuracy ± 2.5 %. The DATA LOGGERs were installed in the milking parlors and cowsheds for five days. The data of external temperature and relative humidity were compared with the internal data. The results of the measurement were processed by Excel software and verified by statistical software Statistica 12 (ANOVA and TUKEY HSD Test).

3. Theory and modelling

To describe the thermal state of indoor environment it is possible to use the THI. This index is widely used to describe the heat stress and it is also a good indicator of stress temperature environment conditions. According to [2] the THI is determined by the following equation:

$$THI = 0.8 \cdot t_i + \frac{(t_i - 14.4) \cdot RH_i}{100} + 46.4 \quad (1)$$

where THI – temperature–humidity index;
t_i – internal temperature of air, ºC;
RH_i – internal relative humidity of air, %.

The average values including standard deviation were calculated from the results of the measurements for each of the microclimatic parameters (temperature, relative humidity, concentration of CO_2, intensity of illumination and noise) and for the THI.

4. Results and discussion

4.1. The summer period

The results of measurement of the interior temperature, relative humidity and THI in the cowshed and milking parlor on farm A and B during morning and afternoon milking in the summer period including external temperature (t_e) and relative humidity (RH_e) are shown in Table 2 and Figure 1-2.

Table 2

Parameters of thermal comfort in summer period

Location	t_i, ºC	RH_i, %	THI	t_e, ºC	RH_e, %
	Farm A – morning milking				
Cowshed	12.15 ± 1.73 [a]	**86.07 ± 6.01** [a]	54.17 ± 2.86 [a]	13.42 ± 3.13	79.61 ± 11.75
Parlor	19.71 ± 0.76 [b]	**88.00 ± 7.04** [a]	66.85 ± 1.40 [b]		
	Farm A – afternoon milking				
Cowshed	18.81 ± 1.73 [c]	63.30 ± 10.77 [b]	64.07 ± 2.20 [c]	14.92 ± 2.85	73.29 ± 12.53
Parlor	20.47 ± 0.79 [d]	**86.11 ± 8.50** [a]	68.03 ± 1.62 [d]		
	Farm B – morning milking				
Cowshed	17.06 ± 1.09 [e]	83.09 ± 5.78 [c]	62.22 ± 1.74 [e]	15.17 ± 2.83	73.17 ± 12.44
Parlor	18.06 ± 1.22 [f]	82.48 ± 7.58 [c]	63.86 ± 2.01 [c]		
	Farm B – afternoon milking				
Cowshed	19.19 ± 1.30 [b, c]	69.84 ± 7.48 [d]	65.01 ± 1.72 [c, f]	16.24 ± 2.14	68.26 ± 11.42
Parlor	19.41 ± 1.89 [b, c]	72.28 ± 6.14 [d]	65.53 ± 2.88 [f]		

* Different letters (a – f) in the superscript are the sign of statistically significant difference at level P = 0.05 (ANOVA and TUKEY HSD Test)

** The results that exceed allowable limits are highlighted in bold.

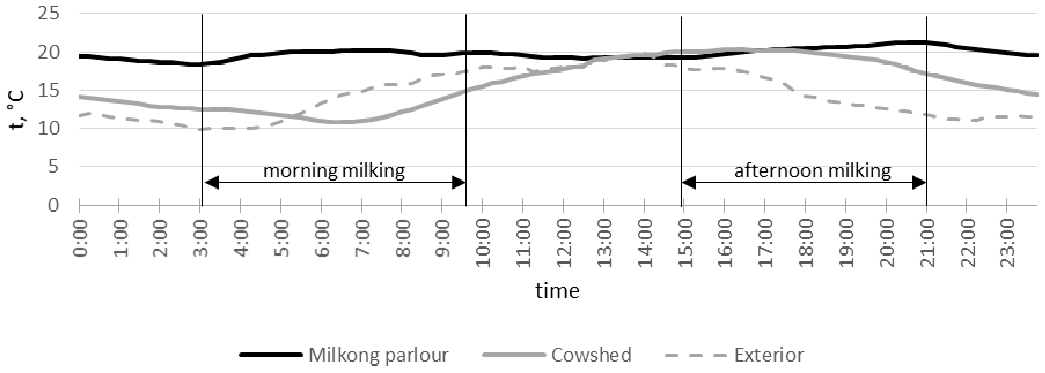

Fig. 1. **Course of temperatures during the summer day on farm A**

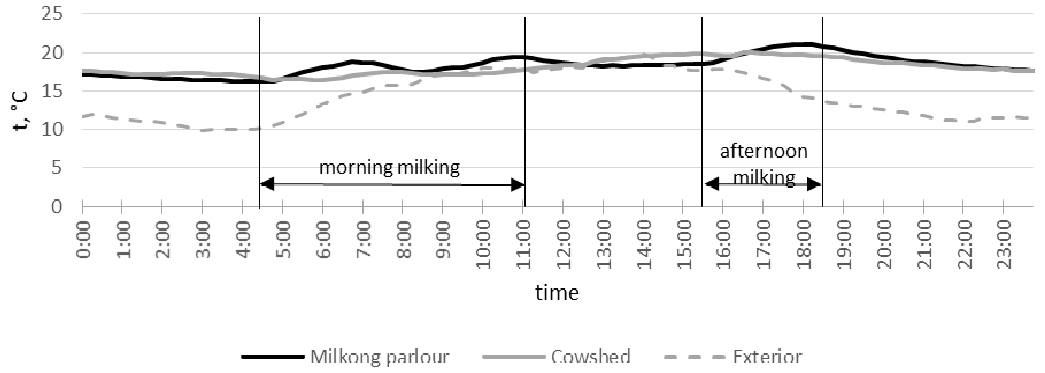

Fig. 2. **Course of temperatures during the summer day on farm B**

In the summer period the internal temperature did not exceed the allowable limits (the external temperature during the measurement was below 20 ºC). On farm A there is bigger difference of the internal temperature between the cowshed with lightweight construction and the milking parlor than on farm B with robust construction of the cowshed (see Figures 1-2). Bigger difference of the internal temperature is in the case of morning milking (on farm A – 7.6 ºC; on farm B – 1 ºC) than during afternoon milking (on farm A – 1.7 ºC; on farm B – no statistically significant difference).

The internal relative humidity in the cowshed and milking parlor is higher than the external relative humidity on both farms. There is no statistically significant difference between the cowshed and the milking parlor for dairy cows (except afternoon milking on farm A). The internal relative humidity also exceeds the allowable limits on farm A (especially in the milking parlors).

The results of the measurement of the CO_2 concentration, illumination and noise in the cowshed and milking parlor on farm A and B during milking in the summer period are shown in Table 3.

Table 3

Parameters of microclimatic, visual and acoustic comfort in summer period

Location	CO_2, %	Illumination, lx	Noise, dB
	Farm A		
Cowshed	0.03 ± 0.00^{a}	286.52 ± 16.85^{a}	55.92 ± 2.85^{a}
Milking parlor	0.05 ± 0.01^{b}	1502.00 ± 447.39^{b}	70.67 ± 8.23^{b}
	Farm B		
Cowshed	0.03 ± 0.00^{a}	229.44 ± 136.02^{a}	60.87 ± 2.88^{c}
Milking parlor	0.10 ± 0.04^{c}	1384.27 ± 228.77^{b}	73.54 ± 4.61^{b}

* Different letters (a, b, c) in the superscript are the sign of statistically significant difference at level P = 0.05 (ANOVA and TUKEY HSD Test)

Each of the parameters of hygienic, visual and acoustic comfort is consistent with the allowable limits. The biggest difference between the cowshed and milking parlor for dairy cows is in the case of illumination (of about five times greater in the parlor than in the barn). The milking parlor is of about 15 dB noisier than the cowshed and the concentration of CO_2 is also higher in the parlor.

4.2. The winter period

The results of the measurement of the interior temperature, relative humidity and THI in the cowshed and milking parlor on farm A and B during morning and afternoon milking in the winter period including external temperature (t_e) and relative humidity (RH_e) are shown in Table 4 and Figure 3-4.

Table 4

Parameters of thermal comfort in winter period

Location	t_i, ºC	RH_i, %	THI	t_e, ºC	RH_e, %
	Farm A – morning milking				
Cowshed	1.62 ± 1.34^{a}	**92.69 ± 5.14^{a}**	35.79 ± 2.85^{a}	-0.43 ± 1.30	94.34 ± 3.65
Milking parlor	16.43 ± 1.71^{b}	**$90.49 \pm 11.89^{a, b}$**	61.25 ± 2.70^{b}		
	Farm A – afternoon milking				
Cowshed	2.49 ± 2.37^{c}	**89.66 ± 7.05^{b}**	37.57 ± 4.68^{c}	0.93 ± 2.27	91.59 ± 6.30
Milking parlor	16.01 ± 1.60^{b}	**97.34 ± 4.71^{c}**	60.73 ± 2.77^{b}		
	Farm B – morning milking				
Cowshed	6.36 ± 2.16^{d}	**$92.17 \pm 4.36^{a, b}$**	44.10 ± 3.16^{d}	0.22 ± 1.89	92.24 ± 6.18
Milking parlor	**11.10 ± 1.55^{e}**	**$90.50 \pm 10.56^{a, b}$**	52.31 ± 2.66^{e}		
	Farm B – afternoon milking				
Cowshed	6.50 ± 2.66^{d}	**$92.25 \pm 5.85^{a, b}$**	40.85 ± 4.73^{f}	0.90 ± 2.19	91.61 ± 5.62
Milking parlor	**10.93 ± 1.84^{e}**	**93.17 ± 7.13^{a}**	51.98 ± 3.02^{e}		

* Different letters (a – f) in the superscript are the sign of statistically significant difference at level P = 0.05 (ANOVA and TUKEY HSD Test)

** The results that exceed (or do not reached) allowable limits are highlighted in bold.

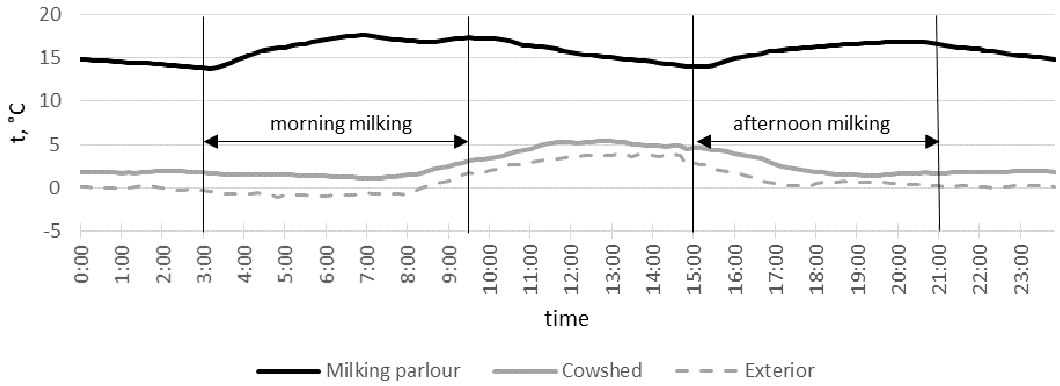

Fig. 3. **Course of temperatures during the winter day on farm A**

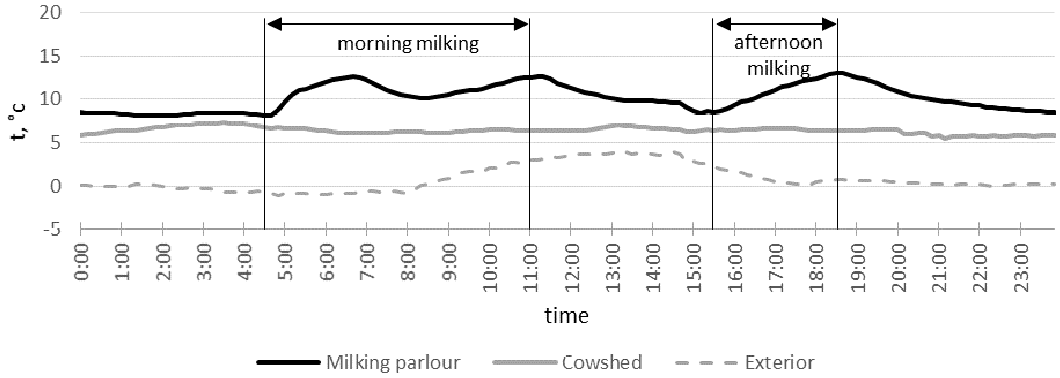

Fig. 4. **Course of temperatures during the winter day on farm B**

Bigger difference of the internal temperature (15 ºC) between the cowshed and the milking parlor is on farm A, because the internal temperature in this cowshed (lightweight construction) corresponds to the external temperature (see Figure 3). However, the internal temperature is consistent with the allowable limits on farm A. On farm B the internal temperature is lower than optimal 14-16 ºC in the milking parlor during the whole milking process, but the difference is just 5 ºC (see Figure 4). The internal temperature is balanced around 5 ºC throughout the day in the cowshed (robust construction) on farm B.

The internal relative humidity is higher than the allowable limit of 85 % on both farms. There is no statistically significant difference between the cowshed and the milking parlor for dairy cows (except afternoon milking on farm A).

Although the THI is below the critical limit of 70 the differences between the THI in the cowshed and milking parlor are in the range of 10-25 in the winter period. Bigger differences are on farm A because of bigger differences between the internal temperature in the milking parlor and the cowshed.

The results of the measurement of the CO_2 concentration, illumination and noise in the cowshed and milking parlor on farm A and B during milking in the winter period are shown in Table 5.

Table 5

Parameters of microclimatic, visual and acoustic comfort in winter period

Location	CO_2, %	Illumination, lx	Noise, dB
	Farm A		
Cowshed	0.035 ± 0.003 [a]	144.15 ± 112.47 [a]	55.04 ± 1.60 [a]
Milking parlor	0.15 ± 0.07 [b]	325.06 ± 15.15 [b]	66.93 ± 6.75 [b]
	Farm B		
Cowshed	0.03 ± 0.01 [a]	89.94 ± 69.07 [c]	51.24 ± 2.79 [a]
Milking parlor	0.15 ± 0.03 [b]	295.96 ± 8.54 [b]	75.72 ± 4.45 [c]

* Different letters (a, b, c) in the superscript are the sign of statistically significant difference at level P = 0.05 (ANOVA and TUKEY HSD Test)

Each of the parameters of the hygienic, visual and acoustic comfort is consistent with the allowable limits. In the winter period the differences between illuminations are not as high as in the summer period (of about three times higher in the milking parlor). The concentration of CO_2 is five times higher in the milking parlor on both farms. The noise is higher by 10-25 dB in the milking parlor.

5. Conclusions

1. In the cowshed with robust construction (farm B) the internal temperature is balanced throughout the day. However, in the cowshed with lightweight construction (farm A) the internal temperature corresponds to the external temperature. The internal temperature is consistent with the allowable limits in both the cowshed and the milking parlor in the summer period. The internal temperature in winter is lower than the allowable limits in a small milking parlor (farm B).
2. Internal relative humidity in the milking parlor is similar as in the cowshed. Internal relative humidity is higher in the winter period than in the summer period and mainly in winter exceeds the allowable limits.
3. The parameters of the microclimatic (CO_2 concentration), visual (illumination) and acoustic (noise) comfort are consistent with the allowable limits. However, in the milking parlor there are worse conditions of the CO_2 concentration and noise, but better conditions of illumination in comparison with the barn.
4. The concentration of CO_2 in the milking parlor is higher in the winter period than in the summer period, which in combination with high internal relative humidity indicates insufficient ventilation in the winter period. In the cowshed the concentration of CO_2 is similar in summer and winter.
5. Noise is in the range of 50-60 dB in the barn and in the range of 65-75 dB in the milking parlor.
6. The intensity of illumination in the milking parlor is about 3-5 times higher than in the cowshed.

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