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THE RELATIONSHIPS BETWEEN TEMPERATURE AND HUMIDITY OUTSIDE AND INSIDE OF A PERMANENTLY OPEN-SIDED COW'S BARN

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Abstract

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The aim of this research was to estimate relations between temperature and humidity outside and inside of a permanently open sides barn for cows. This study was carried out in the period from February 1st, 2009 to January 31st, 2010 at a commercial dairy farm located in the South-Moravian region of the Czech Republic. During the study period temperature and humidity inside and outside the barn were systematically assessed. The research batch had 98 ± 3 cows. The barn had permanently open sides and during summer the main doors were mostly open. The cows in the research barn were of Czech Fleckvieh breed. The air temperature (°C) and humidity (%) were measured every fifteen minutes during the whole study period using 4 data loggers (HOBO technology; RH/Temp/), out of which were three (L1, L2 and L3), located inside the barn (Figure 1) and one (L0) outside the barn. The values of temperature-humidity index (THI) were calculated using the equation proposed by HAHN (1999). Mean daily outside and inside temperatures corresponded with each other, with outside temperatures always being lower than inside temperatures. The difference between the inside and outside temperature was lowest in March (0.01 °C) and highest in October (3.48 °C). Mean values of humidity outside and inside also corresponded; however, they were sometimes higher outside and sometimes inside the barn. The smallest difference between the inside and outside humidity was recorded in August (0.18 %) and the greatest in March (13.21 %). Mean values of temperature-humidity index (THI) inside and outside the barn also corresponded, with outside values being in most cases lower than inside values. The difference between inside and outside THI values was lowest in December (0.07) and highest in October (5.96). The mutual relationships between the values recorded by individual loggers were very close (including the outside logger). Slightly weaker was the relationship between L2 and other, both outside and inside, loggers.

temperature, humidity, THI, dairy cows, barn, climate, microclimate

Dry bulb temperature and humidity are the climatic variables most commonly measured and described in the theory and practice of livestock housing (Charles, 1994). The thermal environment in animal houses is important because of its direct thermal effects on the metabolic rate and efficiency of production by the stock, and its indirect effects on their health and welfare. It is, therefore, important to understand the thermal interactions between stock and their building microclimate and the building microclimate and weather outside, whether the stock are housed for climatic or management reasons. Relationship between animal and its environment determines the degree to which an animal remains in thermal equilibrium with its environment (Finch, 1976). Poor building design and unsuitable microclimates can result in thermal stress on the stock, with consequent productivity losses and risks to welfare. Poor ventilation may also increase the risks to the stock diseases and damaging concentrations of atmospheric contaminants, particularly ammonia. Humidity in animal houses is determined by the interaction between microclimate and evaporation due to the stock (both direct evaporation and those from urine and faces) (Charles, 1981; Clark and Cena, 1981). The ability to regulate temperature is an evolutionary adaptation that allows homeotherms to function in spite of variation in ambient temperature; this ability also allows temperature to be used as a signal to control physiological processes (Bitman *et al.*, 1984). For lactating cows under commercial production conditions, the effects of heat stress that may be experienced during high day ambient temperatures appear to be ameliorated when night temperatures fall (Akari *et al.*, 1987). Nowadays, however, loose housing systems are preferred to reduce labour input with increasing herd sizes as well as to meet animal welfare requirements. In order to minimize investment costs for new or reconstructed stables these loose housing systems are often built in open-fronted buildings or even in buildings open to all sides. As a consequence, the cows are exposed to a wide range of climatic conditions which, in part, can become extreme. This raises the question of whether dairy cows are able to cope with these housing conditions and whether this type of housing provides good living environment to kept animals (Zähner *et al.*, 2004).

In similar research, Walterová *et al.* (2009) found that during the whole year the average daily external temperatures were always lower than the temperatures inside the stable, but the side windows of their barn could be optionally closed. However, this was not the option in our research barn.

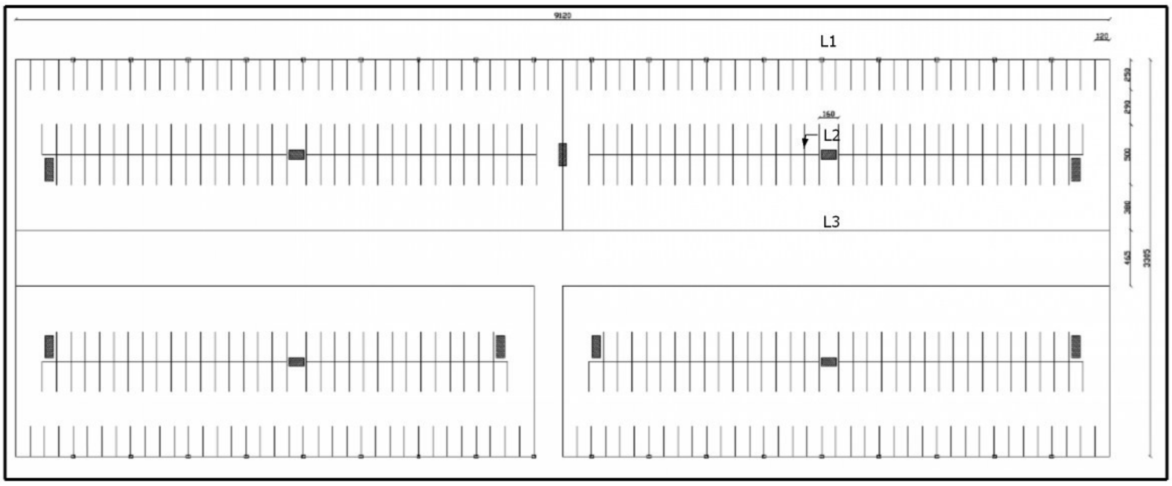
The aim of this research was to estimate relations between temperature and humidity outside and inside of a permanently open-sided barn for cows.

MATERIAL AND METHODS

This study was carried out in the period from February 1st, 2009 to January 31st, 2010 at a commercial dairy farm located in South-Moravian region of the Czech Republic. Climate parameters inside and outside the barn were systematically assessed during the study period.

Housing system and animals

Cows were housed in a free-stall barn which accommodated about 400 cows, divided into 4 batches. The research batch had 98 ± 3 cows. The cows in research barn were of Czech Fleckvieh cattle. The barn had permanently open sides and during the summer period the main doors were mostly open. It was a new type of a barn. There were 1.05 free-stalls per cow and the total area per cow (alleys + free-stalls) was approximately 6.01 m^2. The batch occupied three lines of free stalls. The cows were bedded on solid manure, and there was slatted concrete floor in alleys.



1: *The research barn*
L (1,2 and 3) – logger
■ – water through.

Climate parameters

Climate parameters – air temperature (°C) and humidity (%) were measured every fifteen minutes during the whole study period using 4 data loggers (HOBO technology; RH/Temp/), out of which three (L1, L2 and L3, Figure 1) were located inside the barn and one (L0) outside the barn. Inside loggers were placed: L1 in the window (zero point), L2 on the stall division (7.65 m from the window), and L3 on the feeding fence (13.8 m from the window), all at height of 140 –150 cm (average withers height of cows) in the line with middle water trough (figure 1). From the temperature and humidity values was calculated the temperature-humidity index (THI) according to HAHN (1999):

$$THI = 0.8tdb + (tdb - 14.4) * RH / 100 + 46.4,$$

where:
tdb = temperature in barn,
RH = relative humidity.

RESULTS AND DISCUSSION

Average values of monthly temperatures between loggers inside and outside the barn were similar throughout the year (Table I). The highest difference was found in October, when the average monthly temperatures were higher in the middle of the research quarter (L1, Figure 1) than values measured at the outside logger (3.48 °C). Just in one month (April), the indoor temperatures were lower than outside, and those values were measured at L1 (Table I). Walterová *et al.* (2008) had found that a critical point for dairy cows on second lactation is 22 °C and 25 °C for cows on higher lactations. Considering this claims, the bulk of average summer temperatures did not exceed critical points for a longer period. That does not mean that cows were not exposed to temperatures, which could cause heat stress. The lowest difference was found in the third month, and it was on L1 and it was only 0.01 °C. The L1 had 11 out of 12 lowest differences with L0, which could be explained by position of L1, which is placed in line with a side gap.

The average values of humidity during the year were more diverse. The highest difference was found in March, when monthly humidity on L3 was lower by –13.21% than at L0. There was found 15 negative differences, when RH measured on inside loggers was lower than at L0. The highest differences between inside loggers and L0 were found in first 6 months of research in the period from February to July, then in second research period (August 2009 –January 2010) and most of those were negative. The lowest positive difference was recorded in August and it was 0.18% at L3. Kic *et al.* (1995) suggested that optimal humidity for dairy cows was between 50 and 70. Related to Table II, there were 11 months with higher humidity then 70% and just one month within recommended limits.

The average monthly THI (Table III) values were during most of the year higher inside the barn, than those measured at the outdoor logger. Just in

I: *The average monthly temperatures inside and outside the barn*

Month/L	L0(T)	L1(T)	L2(T)	L3(T)	Δmin/L. *	Δmax/L. **
II 09	0.11	0.89	1.20	2.47	0.78/1	2.36/3
III 09	4.94	4.95	5.90	6.33	0.01/1	1.39/3
IV 09	13.72	13.27	14.69	14.93	–0.45/1	1.21/3
V 09	14.79	15.12	16.17	16.31	0.33/1	1.52/3
VI 09	17.53	18.04	18.29	18.92	0.51/1	1.39/3
VII 09	19.62	20.54	21.72	21.06	0.92/1	2.1/2
VIII 09	20.16	20.60	21.32	21.77	0.44/1	1.56/3
IX 09	16.55	17.04	17.68	18.13	0.49/1	1.58/3
X 09	5.76	8.16	9.24	7.66	1.9/3	3.48/2
XI 09	5.17	5.99	7.04	7.43	0.82/1	2.26/3
XII 09	**–0.32**	0.14	1.43	2.11	0.46/1	2.43/3
I 10	**–4.01**	–3.86	–2.02	–1.54	0.15/1	2.47/3

*minimum difference between one of the loggers (1, 2 and 3) and logger 0
**maximum difference between one of the loggers (1, 2 and 3) and logger 0

II: *The average monthly humidity inside and outside the barn*

Month/L	L0(RH)	L1(RH)	L2(RH)	L3(RH)	Δmin/L.*	Δmax/L. **
II 09	84.04	85.75	77.76	84.35	0.31/3	–6.28/2
III 09	89.27	79.74	90.81	76.06	1.08/2	–13.21/3
IV 09	59.85	60.83	55.67	55.10	0.95/1	–4.75/3
V 09	71.42	64.21	66.21	66.15	–5.21/2	–7.21/1
VI 09	78.64	77.38	73.86	74.96	–1.26/1	–4.78/2
VII 09	74.36	71.36	66.38	68.96	–3.00/1	–7.98/2
VIII 09	71.92	70.16	67.72	72.10	0.18/3	–4.20/2
IX 09	75.90	74.04	71.22	69.69	–1.86/1	–6.21
X 09	89.32	89.74	87.93	83.27	0.42/1	–6.05/3
XI 09	92.07	94.71	92.81	89.98	0.74/2	2.64/1
XII 09	83.77	89.60	85.37	82.03	–1.60/2	4.17/1
I 10	85.60	89.34	87.63	83.56	–2.04/3	3.74/1

*minimum difference between one of the loggers (1, 2 and 3) and loggers 0
**maximum difference between one of the loggers (1, 2 and 3) and logger 0

one month was found a negative value of THI inside the barn, related to L0 and it was in a comfortable period of the year for dairy cows (April, L1). The differences between L0 and inside loggers were higher in colder and moderate periods of the year, so the highest positive difference was recorded in October (5.96 on L2). However highest values of THI were evidenced in summer months (June – 62.89, July – 65.89 and August – 66.67) and those values were close to critical points, if we considered Kadzere *et al.* (2002) that values bellow 70 are comfortable.

In tables IV, V and VI are shown correlations between individual loggers throughout the year. The maximum values for temperatures were between L1 and L2 in December (0.999), and the minimum of correlation was found also between those two loggers in July (0.875). Higher correlations of temperatures were recorded in autumn and winter months, whereas lower were more frequent in spring and summer months.

The highest correlation between average RH values was in June (between L1 and L0) and it was 0.998. The lowest correlation was found between L2 and L1 in August and it was 0.489. Almost all maximum and minimum correlations were found in summer months (June, July and August), just two were in May and one in December.

Correlation between average monthly THI values, showed relatively high correlation. The lowest value was found between L2 and L1 in August (0.849), and also the highest between those two loggers in May (0.998). Maximum and minimum values of correlation for THI were dispersed through all seasons. All minimum correlations between L0 and inside loggers were found in March (Table VI).

III: *The average monthly THI inside and outside the barn*

Month/L	L0(THI)	L1(THI)	L2(THI)	L3(THI)	Δmin/L. *	Δmax/L. **
II 09	34.47	35.52	37.10	38.31	1.05/1	3.84/3
III 09	41.91	42.82	43.40	45.33	0.91/1	3.42/3
IV 09	56.97	56.33	58.31	58.64	–0.64/1	1.67/3
V 09	58.51	58.96	60.51	60.71	0.45/1	2.20/3
VI 09	62.89	63.65	63.91	64.92	0.76/1	2.03/3
VII 09	65.98	67.21	68.64	67.82	1.23/1	2.66/2
VIII 09	66.67	67.23	68.14	69.13	0.56/1	2.46/3
IX 09	61.27	61.99	62.88	63.50	0.72/1	2.23/3
X 09	43.29	47.33	49.25	46.92	3.63/3	5.96/2
XI 09	42.04	43.23	45.20	46.07	1.19/1	4.03/3
XII 09	33.81	33.74	36.47	38.01	– 0.07/1	4.20/3
I 10	27.43	27.00	30.40	31.85	– 0.43/1	4.42/3

*minimum difference between one of the loggers 1,2 and 3 and loggers 0
**maximum difference between one of the loggers 1,2 and 3 and logger 0

IV: *Maximum and minimum correlations between temperature values*

Logger	L0(T)	L1(T)	L2(T)	L3(T)
L0(T)	1	0.994/X 09	0.995/X 09	0.996/X 09
L1(T)	0.949/III 09	1	0.999/XII 09	0.996/XII 09
L2(T)	0.882/VII 09	0.875/VII 09	1	0.998/X 09
L3(T)	0.920/III 09	0.890/IX 09	0.866/VII 09	1

Maximum values are above diagonal line.
Minimum values are bellow diagonal line.
Value/month year.

V: *Maximum and minimum correlations between humidity values*

Logger	L0(RH)	L1(RH)	L2(RH)	L3(RH)
L0(RH)	1	0.998/VI 09	0.991/VI 09	0.988/VI 09
L1(RH)	0.913/XII 09	1	0.994/VI 09	0.997/V 09
L2(RH)	0.812/V 09	0.489/VIII 09	1	0.998/VII 09
L3(RH)	0.917/VIII 09	0.691/VIII 09	0.788/V 09	1

Maximum values are above diagonal line.
Minimum values are bellow diagonal line.
Value/month year.

VI: *Maximum and minimum correlations between THI values*

Logger	L0(THI)	L1(THI)	L2(THI)	L3(THI)
L0(THI)	1	0.991/V 09	0.994/X 09	0.996/X 09
L1(THI)	0.909/III 09	1	0.998/V 09	0.995/V 09
L2(THI)	0.879/III 09	0.849/VIII 09	1	0.994/XI 09
L3(THI)	0.844/III 09	0.925/IX 09	0.862/VII 09	1

Maximum values are above diagonal line.
Minimum values are bellow diagonal line.
Value/month year.

CONCLUSIONS

A cow barn with permanently opened sides represents a type of housing with maximum ventilation. In spite of this the mean monthly values of temperature, humidity and THI inside and outside the barn did not significantly vary. The maximum difference in temperature was 3.48 °C, humidity 13.21 % and THI 5.96. Higher temperature recorded in summer months was compensated by lower humidity, thus THI did not exceed the critical value (70). A close relationship between the values recorded by individual loggers was found (including the outdoor logger). Slightly weaker was the relationship between L2 and other, both outside and inside, loggers.

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SOUHRN

Vztahy mezi teplotou a vlhkostí vně a uvnitř stáje pro dojnice s trvale otevřenými stěnami

Cílem této práce bylo kvantifikovat vztahy mezi teplotou a vlhkostí vně a uvnitř stáje s trvale otevřenými stěnami. Sledování proběhlo od 1. února 2009 do 31. ledna 2010 v běžné stáji pro dojnice v Jihomoravském regionu České republiky. Během studie byly pravidelně hodnoceny teplota (T) a relativní vlhkost (RH) vně a uvnitř stáje. Pokusnou skupinu tvořilo 98 ± 3 krav. Stáj měla trvale otevřené boční stěny a během léta často otevřena také hlavní vrata. Dojnice ve sledované stáji byly českého strakatého plemene skotu. Teplota (°C) a relativní vlhkost (%) byly měřeny každých patnáct minut během celého pokusného období pomocí čtyř čidel (HOBO technologie RV/T), přičemž tři z nich (L1, L2 a L3) byly umístěny ve stáji (Obr. 1) a čtvrté (L0) bylo umístěno vně stáje. Hodnoty teplotně vlhkostního indexu (THI) byly spočteny podle rovnice uvedené HAHNEM (1999). Průměrné denní teploty vně a uvnitř stáje měly podobný průběh, přičemž teploty vně stáje byly vždy nižší než uvnitř. Rozdíl mezi vnitřní a vnější teplotou byl nejnižší v březnu (0,01 °C) a nejvyšší v říjnu (3,48 °C). Průměrné relativní vlhkosti vně a uvnitř stáje měly rovněž podobný průběh, avšak v některých případech byly vyšší vně stáje než uvnitř, v některých případech tomu bylo naopak. Rozdíl mezi vnitřní a vnější vlhkostí byl nejnižší v srpnu (0,18 %) a nejvyšší v březnu (13,21 %). Průměrné hodnoty THI (teplotně vlhkostní index) vně a uvnitř stáje měly rovněž podobný průběh, přičemž hodnoty vně stáje byly téměř ve všech případech nižší než uvnitř. Rozdíl mezi vnitřní a vnější hodnotou THI byl nejnižší v prosinci (0,07) a nejvyšší v říjnu (5,96). Byl zaznamenán poměrně těsný vztah pro měřené veličiny mezi různými čidly, včetně venkovního. Relativně nejméně těsný vztah byl u čidla L2, a to jak k čidlu venkovnímu, tak ke zbývajícím čidlům umístěným uvnitř stáje.

teplota, vlhkost, THI, dojnice, stáj, klima, mikroklima

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