ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LX 43 Number 6, 2012

THE EFFECT OF LOW AND HIGH BARN TEMPERATURES ON BEHAVIOUR AND PERFORMANCE OF HOLSTEIN DAIRY COWS

M. Večeřa, D. Falta, G. Chládek, L. Máchal

Received: June 25, 2012

Abstract

VEČEŘA, M., FALTA, D., CHLÁDEK, G., MÁCHAL, L.: *The effect of low and high barn temperatures on behaviour and performance of Holstein dairy cows.* Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 6, pp. 343–350

The experiment was carried out at the University Training Farm in Žabčice (the Czech Republic; location 49°0'51.081"N, 16°36'14.848"E, 179 m.a.s.l) over the period of one year (1st July to 30th June). The assessment of temperature impact was based on data from 16 hottest days (H) and 16 coldest days (L). The experimental group consisted of 70 cows in various stage of lactation (30d–210d) and parity (1–8). The cows were housed in a section (one quarter) of a free-stall barn with 77 stalls in three rows. Row A was located peripherally, close to the side wall, row B was in the middle and row C was situated centrally, close to the feed table. The cows were observed weekly on the same day at 9.00 a.m. The microclimate characteristics were recorded daily: temperature in hot (H) resp. cold (L) period was in average 27.1°C resp. – 1.47 °C, and relative humidity 54.4% resp. 77.3%, and THI 75 resp. 33.
Behaviour was described by a number of cows standing or lying down, number of cows lying down on their left or right side and row preference (A, B, C) in the resting area. Cow Comfort Index (CCI – a number of cows lying down at given time) was calculated. A total of 1587 observations were analysed. A number of cows lying down (922) was significantly higher than that of standing cows (665). Milk production was significantly higher in hot (H) period (by 1.0–1.7 kg). There was an interaction in milk production between period and standing. In H period the standing cows produced more milk, in L period vice versa. The cows with non-significant tendency towards left-side laterality produced more milk (by 1.2 kg). No interaction was found between period and laterality for milk production. All the observed parameters significantly differed between rows A, B and C. Row A was the most preferred, the cows preferring it were young (low number of lactation) with greatest milk production. The cows in row C had the lowest milk production and were in late lactation. The interaction was found between period and row affected number of lactation ($P < 0.01$) and number of cows ($P < 0.05$). In H period the row A was preferred by older cows (high number of lactation), while in L period it was preferred by younger cows. The cows in H period used row C less while in L period they preferred it.

temperature, behaviour, Holstein, cows

Although the process of domestication brought about a number of important, or even essential, changes in farm animal performance or exterior, their environmental requirements remained relatively invariable throughout their phylogenesis. The impact of environmental factors on domesticated animals is extremely complex and difficult to define. The more altered the original environmental conditions, the greater responsibility of the breeder to provide adequately for animals' needs (Chládek, 2004).

Barn microclimate is, together with nutrition, type of housing and animal handling, one of the main factors affecting an animal organism. It affects cows' welfare and performance and consequently herd profitability. The barn microclimate is defined by air temperature, relative humidity, air velocity and content of various components – gasses, dust, microorganisms (Matějka, 1995). According to Bílek (2002) barn temperature is the most influential factor. A negative impact of high temperature is enhanced by air humidity Koukal (2001). With increasing relative humidity, heat tolerance and stress resistance of cows decreases (Doležal *et al*., 2003). Temperature-Humidity Index (THI) accounts for the combined effects of temperature and relative humidity (West, 2003).

Cow Comfort Index (or Cow Comfort Quotient) was first described more than 10 years ago and is the most common criterion used for a cow welfare assessment. It is calculated as a proportion of cows lying down at given time (Grant, 2009; Rae, 2012). Time spent lying down indicates housing quality and a comfortable lying-down area is one of the most important housing design criteria for dairy cows (Ito *et al*., 2009). An amount of time spent comfortably lying down is fundamental for cows' welfare (Thorne, 2008). It can be extended by various means, e.g. provision of an additional bedding (Colam-Ainsworth, 1989; Drissler, 2005). A quality of stall surface, a number of stalls and an area available for each cow are important characteristics affecting lying behaviour (Fregonesi *et al*., 2007). In order to maintain good welfare of cows it is essential to analyse their behavioural responses to barn microclimate changes.

In this paper we deal with the hypothesis that hot (H) and cold (L) period will not affected by lying, standing, laterality of lying and row preference in free-stall barn.

MATERIAL AND METHODS

The experiment was designed to assess the effect of low and high barn temperatures on behaviour and performance of dairy cows. It was carried out at the University Training Farm in Žabčice (the Czech Republic; location 49°0'51.081"N, 16°36'14.848"E, 179 m.a.s.l.). The observed section of the resting area (¼ of the barn) comprised of 77 comfortable stalls distributed into 3 rows. „Row A (29 stalls; avg. widht cubicle – 114.0 cm; avg. length cubicle – 217.7 cm; avg. length from neck rail – 205.1 cm) was located peripherally, close to the side wall. Row B (24 stalls; avg. widht cubicle – 114.0 cm; avg. length cubicle – 242.5 cm; avg. length from neck rail – 204.0 cm) was in the middle and row C (24 stalls; avg. widht cubicle – 114.0 cm; avg. length cubicle – 241.2 cm; avg. length from neck rail – 205.6 cm) was situated centrally in the building, close to the feed alley." The studies by Walterová *et al*. (2009) or Zejdová *et al*. (2011) were carried out in the same barn. The dairy cows housed in the experimental barn were of Holstein breed. The observed section accommodated 70 cows on average; they were in various stage of lactation (30d–210d) and parity (1–8). There were no dry cows.

The data were collected over one year (1st July to 30th June). The assessment of temperature impact was based on data from 16 hottest days (H) and 16 coldest days (L). The cows were observed weekly on the same day at 9.00 a.m., after milking and before scraping manure in walkways. Behaviour was described by a number of cows standing or lying down, a number of cows lying down on their left or right side and row preference (A, B, C) in the resting area. Cow Comfort Index (CCI – a number of cows lying down at given time) was calculated. The microclimate characteristics (air temperature and relative humidity) were recorded by HOBO data loggers. Their detailed location and function were described in Walterová et al. (2009). THI values were calculated using the following equation Hahn (1999):

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

where:
tdb ... barn temperature
RH ... relative humidity.

The calculated values were statistically evaluated via GLM procedure and chi-square test (Statistica 9.0.).

RESULTS AND DISCUSSION

Lying and standing behaviour

Barn microclimate characteristics are presented in Tab. I. Mean temperature in hot period (H) was 27.1 °C, humidity 54,4% and THI 75, while in the cold period (L) the respective values were significantly different: –1.47 °C, 77.3 % and 33.

Tab. II, presents values of a total 1587 observations, out of which 789 were taken in H period and 798 in L period. The observed cows were either lying down (922) or standing (665). The cows during hot days produced more milk per day (by 1.7 kg, $P < 0.01$) than in cold days.

The cows preferred lying down to standing ($P < 0.01$). Milk production of the lying cows was non-significantly lower (by 0.4 kg). The differences in number and stage of lactation in lying and standing cows were also minor.

The combination of lying behaviour and the barn temperature revealed that the cows standing in hot days produced the highest quantity of milk ($P < 0.05$) while in cold days the lowest. An increase in barn temperature and humidity causes a decrease in dry matter intake (DMI) and thus also in milk production (West, 2003). Igono *et al.* (1992) claims that heat stress (above 21 °C) reduces milk production compared to thermo neutral environment. However, our results were rather opposite; the cows in hot days (mean of 27 °C) produced more milk. Zejdová *et al.* (2010) found similar results. They presumed a summer season in general positively stimulated cows' metabolism and thus enhanced milk production, despite the temporary (few days) heat stress.

Cows spend on average 13 h/d lying down (Houpt, 1998). Tucker *et al.* (2004) specified the range between 9.4–14.7 h/d, with an average lying bout

I: *Barn climatic characteristics*

Climatic characteristics			Temperature period		
			High	Low	Sig.
Temperature (° C)	mean	12.83	27.1	−1.47	**
	min.	*−2.72*	*25.4*	*−2.72*	
	max.	*30.1*	*30.1*	*−0.36*	
Relative humidity (%)	mean	65.8	54.4	77.3	**
	min.	*45.6*	*45.6*	*46.5*	
	max.	*87.3*	*61.2*	*87.3*	
THI	mean	54	75	33	**
	min.	*30.2*	*72.6*	*30.2*	
	max.	*79.1*	*79.1*	*39.0*	

Values differ if marked with * (P < 0.05) and ** (P < 0.01)

of 0.9–1.4h. The proportion of cows lying down (CCI) should exceed 85% in free stall barns with adequate management (Grant, 2009; Rae, 2012). We found out a considerably lower number of lying cows (CCI = 58%) which could probably be related to high temperatures. At temperatures exceeding 20 °C the number of cows lying down decreases, thus affecting CCI values (Zejdová *et al*., 2011). It is generally acknowledged that the body of a standing cow offers a much greater surface for heat loss than that of a lying cow. This corresponds with the fact that our cows standing in the hot period produced more milk than those standing in the cold period.

Laterality of lying behaviour

The effect of environmental heat and cold on laterality of lying behaviour and milk production is described in Tab. III. Cows produced more milk in hot days (by 1 kg, P < 0.05) than in cold days. Cows lying on their left side produced more milk (by 1.2 kg, P < 0.05) than cows lying on their right side. Laterality had no association with a number and stage of lactation. The combination of laterality and barn temperature revealed that cows lying on their left side produced more milk in both high and low temperatures but the actual interaction of both factors was not significant.

A non-significant tendency towards a left-side preference was also found by Hrouz *et al*. (2007) where 53–70% of their experimental animals preferred the left side to rest on. Tucker *et al*. (2009) observed a left-side laterality in free-housed dry cows; however, the authors admited that cows in pens or on pasture may exhibit no laterality. Although the cows show no overall laterality as a group, they still may have a strong preference as individuals (Gibbons *et al*., 2012). Zejdová *et al*. (2011) found out that older cows (lactation 4 and older) preferred left side more often than younger cows (lactation 2 and 3). In our experiment, the cows preferring the left side had a higher milk production. We speculated that this was due to the anatomical differences in the left and right lung. A greater respiration capacity of the right lung allowed better lung ventilation in cows lying on their left side.

Row preference

Out of the cows lying down, 890 cows were lying in the stalls and 32 outside the stalls. Out of the standing cows, 218 cows were standing in the stalls and 447 outside the stalls.

Tab. IV, shows that there were 447 cows lying or standing in stalls in row A (peripheral row), 309 in row B (middle row) and 352 in row C (central row). Milk production was again greater in hot days (by 1.3 kg). The cows preferred row A (447 cows, P < 0.01) to row B (309 cows) or C (352 cows). The cows in row A were younger – number of lactation was smaller-than in row B. The cows in row C had the lowest milk production and were further in lactation (P < 0.01) compared to rows A and B. We looked into the combined effect of temperature and row preference. A number of cows in row C in hot period (H) was smallest and in cold period (L) greatest. The interaction was also significant in number of lactation; row A was preferred by older cows (greater number of lactation) in hot days (H) and by younger cows in cold days (L).

The preference of peripheral (A) row in our case agrees with the results of Wagner – Storch *et al*. (2003) who suggested that the preference of peripheral rows of stalls may be due to a better ventilation of air near sidewalls. On the contrary, Natzke *et al*. (1982) observed that the inner rows of stall are preferred to the outer ones. In the study of Doležal (2003) the cows preferred the rows situated close to the feed table rather than the outer rows further from it. These results were confirmed by Gaworski *et al*. (2003). Večeřa *et al*. (2011) also observed the tendency of cows to occupy the first (closest) or second (middle) row from the feed table, given the choice, when coming from the milking parlour. Večeřa *et al*. (2012) further specified that the rows closest to the feed table and middle rows were preferably occupied by cows in late lactation.

CONCLUSIONS

Our results led us to a conclusion that the higher temperatures positively affected milk production of the experimental animals. The cows tended

II: *Milk production, number and stage of lactation with respect to high and low temperature periods, lying and standing*

	mean	Temperature period			Lie x Stand			Temperature period x Stand or Lie					
		High	Low	Sig.	Lie	Stand	Sig.	High x Lie	High x Stand	Low x Lie	Low x Stand	Sig.	Sig. of interaction
n	1 587	789	798	NS	922	665	**	430 [a]	359 [b]	492 [a]	306 [b]	*	NS
Milk production (kg/cow/day)	32.9	33.7 [a]	32.0 [b]	**	32.7	33.1	NS	33.2 [ab]	34.3 [a]	32.2 [b]	31.7 [b]	*	*
Lactation number	3.00	2.99	3.02	NS	3.06	2.94	NS	3.01	2.95	3.09	2.91	NS	NS
Lactation stage (days)	169.7	169.4	170.1	NS	172.4	166.1	NS	175.8	161.7	169.4	171.2	NS	NS

Values within the row differ if marked with * ($P < 0.05$) and ** ($P < 0.01$) or difference is not significant (NS)
Values within the row differ if marked with different letters a, b, c

III: *Milk production, number and stage of lactation with respect to high and low temperature periods and laterality of laying*

	mean.	Temperature period			Side			Temperature period x Side					
		High	Low	Sig.	Left	Right	Sig.	High x Left	High x Right	Low x Left	Low x Right	Sig.	Sig. of inter.
n	890	430	460	NS	467	423	NS	219	211	248	212	NS	NS
Milk production (kg/cow/day)	32.6	33.2 [a]	32.2 [b]	*	33.2 [a]	32.0 [b]	*	34.0 [a]	32.3 [b]	32.6 [b]	31.7 [b]	*	NS
Lactation number	3.05	3.02	3.08	NS	3.09	3.00	NS	3.00	3.04	3.18	2.96	NS	NS
Lactation stage (day)	172.9	175.8	170.2	NS	167.9	178.5	NS	168.6	183.3	167.2	173.7	NS	NS

Values within the row differ if marked with * ($P < 0.05$) and ** ($P < 0.01$) or difference is not significant (NS)
Values within the row differ if marked with different letters a, b, c

IV: *Milk production, number and stage of lactation in cows with respect to high and low temperature periods and row preference*

	mean	Temperature period			Row				Temperature period x Row							
		High	Low	Sig.	A	B	C	Sig.	High x A	High x B	High x C	Low x A	Low x B	Low x C	Sig.	Sig. of interaction
n	1 108	549	559	NS	447 [a]	309 [b]	352 [b]	**	251 [a]	150 [c]	148 [c]	196 [b]	159 [c]	204 [b]	*	*
Milk production (kg/cow/day)	32.8	33.5 [a]	32.2 [b]	**	33.6 [a]	33.2 [a]	31.5 [b]	**	34.1 [a]	34.2 [a]	31.7 [b]	33.1 [ab]	32.3 [ab]	31.4 [b]	*	NS
Lactation number	3.06	3.03	3.08	NS	2.94 [a]	3.18 [b]	3.10 [ab]	*	3.08 [a]	3.05 [ab]	2.93 [ab]	2.76 [b]	3.29 [a]	3.22 [a]	**	**
Lactation stage (days)	169.6	170.5	168.8	NS	160.2 [a]	164.8 [a]	185.8 [b]	**	162 [a]	156.5 [a]	199 [b]	157.8 [a]	172.7 [ab]	176.3 [ab]	*	NS

Values within the row differ if marked with * ($P < 0.05$) and * ($P < 0.01$) or difference is not significant (NS)
Values within the row differ if arked with different letters a, b, c

to rest lying down rather than standing but not quite to the extent quoted in literature. The barn temperature had no effect on the proportion of lying and standing cows. The cows showed non-significant tendency towards left-side laterality. The cows resting on the left side produced more milk per day. We found a strong preference for some rows of stalls. The outer, peripheral stalls, were most frequently occupied, they were preferred by younger cows with the highest milk production. The stalls closest to the feed table were preferred by cows in late lactation with lower milk production. The interaction between barn temperature and row of stalls affected number of lactation ($P < 0.01$) and number of cows ($P < 0.05$).

We didn't prove our hypothesis, because all monitored parameters (lying, standing, laterality of lying and row preference in free-stall barn) were affected by hot (H) and cold (L) period.

SUMMARY

The aim of this study was to assess the effect of low and high barn temperatures on behaviour and performance of Holstein dairy cows. The experiment was carried out at the University Training Farm in Žabčice (the Czech Republic; location 49°0'51.081"N, 16°36'14.848"E, 179 m.a.s.l.)over the period of one year (1st July to 30th June). The assessment of temperature impact was based on data from 16 hottest days (H) and 16 coldest days (L). The experimental group consisted of 70 Holstein dairy cows in various stage of lactation (30d–210d) and parity (1–8). The cows were housed in a section (one quarter) of a free-stall barn with 77 stalls in three rows. Row A (29 stalls) was located peripherally (next to the side wall), row B (24 stalls) was in the middle and row C (24 stalls) was situated centrally in the building, close to the feed table. The cows were observed weekly on the same day at 9.00 a.m., after milking and before scraping manure in walkways (rest period).

The microclimatic characteristics, air temperature (°C) and relative humidity (%) were recorded daily and THI was calculated (Tab. I). Behaviour was described by a number of cows standing or lying down, number of cows lying down on their left or right side and row preference (A, B, C) in the resting area. A total number of observations was 1587. A number of cows lying down (922) was significantly higher than that of standing cows (665). Milk production was significantly higher in hot (H) period (by 1.0–1.7 kg). There was an interaction in milk production between period and standing. In H period the standing cows produced more milk, in L period vice versa (Tab. II). The cows with non-significant tendency towards left-side laterality produced more milk (by 1.2 kg). No interaction was found between period and laterality for milk production (Tab. III).

All the observed parameters significantly differed between rows A, B and C (Tab. IV.). Row A was the most preferred, the cows preferring it were young (low number of lactation) with the greatest milk production. The cows in row C had the lowest milk production and were in late lactation. The interaction between period and row affected number of lactation ($P < 0.01$) and number of cows ($P < 0.05$). In H period the row A was preferred by older cows (high number of lactation), while in L period it was preferred by younger cows. Cows in H period used the row C less while in L period they preferred it.

Acknowledgement

This study was supported by the Research plan No. MSM6215648905 "Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change", which was financed by the Ministry of Education, Youth and Sports of the Czech Republic and by Internal Grant Agency of FA, MENDELU TP 1/2012.

REFERENCES

BÍLEK, M., 2002: Welfare ve stájích pro skot, (Welfare in barns for cattle, in Czech), Praha: Ústav zemědělských a potravinářských informací, 32 s. ISBN 80-7271-112-1.

CHLÁDEK, G., 2004: Složení mléka jako levný a účinný prostředek pro hodnocení chovného prostředí dojnic. (Milk composition as a cheap and efficient tool for evaluation of housing facilities for dairy cows, in Czech). In: HANUŠ, O. a kol. Aktuální problémy řízení v chovu skotu. (Ccurrent problems of cattle farming, in Czech). Rapotín. Agrární komora Olomouckého kraje, Okresní agrární komora Šumperk, s. 56–60.

COLAM-AINSWORTH, P., LUNN, G. A., THOMAS, R. C., EDDY, R. G., 1989: Behaviour of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers. The Veterinary Record, Vol. 125, Issue 23, s. 573–575. ISSN 0042-4900.

DOLEŽAL, O., 2003: Vyhodnocení čtyřřadové dispozice boxových loží metodou preferenční testace. (Evaluation of a four-row disposition of lying boxes using the method of preference tests, in Czech). [on-line], Dostupné z: www.mze-vyzkum-infobanka.cz/DownloadFile/41757.aspx. (cit. 1. 3. 2012).

DOLEŽAL, O., DOLEJŠ, J., KNÍŽKOVÁ, I., KUNC, P., BÍLEK, M., ČERNÁ, D., 2003: Komfortní ustájení vysokoprodukčních dojnic. (Comfort housing for high performance dairy cows, in Czech). Výzkumný ústav živočišné výroby, Uhřiněves. ISBN 80-86454-28-2.

DRISSLER, M., GAWORSKI, M., TUCKER, C. B., WEARY, D. M., 2005: Freestall maintenance: Effects on lying behavior of dairy cattle. Journal of dairy science, 88 (7): 2381–2387, JUL 2005. ISSN 0022-0302.

FREGONESI, J. A., TUCKER, C. B., WEARY, D. M., 2007: Overstocking reduces lying time in dairy cows. Journal of dairy science, 90 (7): s. 3349–3354. ISSN 0022-0302.

GAWORSKI, M. A., TUCKER, C. B. and WEARY, D. M., 2003: Effects of two free-stall designs on dairy cattle behavior. Proceedings of the Fifth International Dairy Housing Conference, American Society of Agricultural Engineers, St. Joseph, pp. 139–146.

GIBBONS, J., MEDRANO-GALARZA, C., PASSILLE, A. M., RUSHEN, J., 2012: Lying laterality and the effect of IceTag data loggers on lying behaviour of dairy cows. Applied Animal Behaviour Science, 136 (2): s. 104–107. ISSN 0168-1591.

GRANT, R., 2009: A quick check for cow comfort. Dairy basics. Excerpts from William H. Miner Agricultural Research Institute Farm Report, September 2009.

HAHN, G. L., 1999: Dynamic response sof cattle to thermal heat loads. Journal of Animal Science. ISSN 0021-8812.

HOUPT, K. A., 1998: Domestic behaviour for veterinarians and animal scientists, 3rd ed. Iowa state University Press, s. 98–103. ISBN 0-8138-1061-2.

HROUZ, J., MÁCHA, J., KLECKER, D., VESELÝ, P., 2007: Etologie hospodářských zvířat. (Ethology of farm animals, in Czech). Mendelova zemědělská a lesnická univerzita v Brně, 185 s. ISBN 978-80-7157-463-7.

IGONO, M. O., BJOTVEDT, G., SANFORD-CRANE, H. T., 1992: Environmental profile and critical temperature effects on milk production of Holstein cows in desert climate. International journal of biometeorology, 36 (2): s. 77–87, DOI: 10.1007/BF01208917.

ITO, K. et. al., 2009: Lying behaviour: Assessing within – and between – herd variation in free-stall-housed dairy cows. Journal of dairy science, 92 (9): s. 4412–4420, ISSN 0022-0302.

KOUKAL, P., 2001: Výživa dojnic v teplém počasí podle zkušenosti z léta 2000, (Nutrition of dairy cows during periods of hot weather, experiences from the summer of 2000, in Czech). Farmář, 9: 75–76. ISSN 1210-9789.

NATZKE, R. P., BRAY, D. R. and EVERETT, R. W., 1982: Cow Preference for Free Stall Surface Material. Journal of Dairy Science 65, 146–153. ISSN 0022-0302.

MATĚJKA, J., 1995: Teplotní a vlhkostní poměry stájí pro skot v zimě, (Ethology of farm animals, in Czech). Náš chov, 12, s. 22–23. ISSN 0027-8068.

RAE, B., 2012: Dairy Diagnostic Tool Box. Worksheet 9: Calculating Cud Chewing Index & Cow Comfort Quotient. University of Minnesota [on line]. Dostupné z: http://www.ansci.umn.edu/dairy/toolbox/toolbox.htm.

THORNE, M., 2008: Busy cows need comfort when they take a rest. Farmes weekly (10/2008). ISSN 0014-8474.

TUCKER, C. B., WEARY, D. M., RUSHEN, J., PASSILLÉ, A. M., 2004: Designing Better Environments for Dairy Cattle to Rest. Advances in Dairy Technology (2004) Volume 16, p. 39.

TUCKER, C. B., COX, N. R., WEARY, D. M., SPINKA, M., 2009: Laterality of lying behaviour in dairy cattle. Applied animal behaviour science, 120 (3–4): p. 125–131, SEP 2009. ISSN 0164-1591.

VEČEŘA, M., STUDENÝ, S., POLÁK, O., ZEJDOVÁ, P., FALTA, D., CHLÁDEK, G., 2012: Vliv pořadí laktace na celodenní preferenci boxové řady dojnic českého strakatého plemene. (Effect of rank of lactation on the all-day preference of box row in dairy cows of the Czech Red Pied breed, in Czech). [CD-ROM]. In: Animal Breeding. s. 62–66. ISBN 978-80-7157-224-4.

VEČEŘA, M., FALTA, D., ZEJDOVÁ, P., POLÁK, O., STUDENÝ, S., CHLÁDEK, G., 2011: Výběr řady boxů dojnicemi po návratu z ranního dojení. (Selection of box row by dairy cows after the return from the morning milking, in Czech). [CD-ROM]. In: MendelNet 2011 – Proceedings of International Ph.D. Students Conference. s. 56. ISBN 978-80-7375-563-8.

WAGNER-STORCH, A. M., PALMER, R. W. and KAMMEL, D. W., 2003: Factors Affecting Stall Use for Different Freestall Bases. Journal of Dairy Science 86, 2253–2266. ISSN 0022-0302.

WALTEROVÁ, L., ŠAROVSKÁ, L., FALTA, D., CHLÁDEK, G., 2009: Vztah mezi vybranými klimatickými prvky uvnitř a vně stáje dojnic v průběhu roku. (Relationship between some selected climatic parameters measured inside and outside barns for dairy cows during the year, in Czech). Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis (4) 2009, s. 125–132. ISSN 1211-8516.

WEST, J., W., 2003: Effects of Heat-Stress on Production in Dairy Cattle. Journal of Dairy Science 86, 2131–2144. ISSN 0022-0302.

ZEJDOVÁ, P., WALTEROVÁ, L., FALTA, D., CHLÁDEK, G., 2010: Letní teploty stájového ovzduší a jejich vliv na mléčnou užitkovost dojnic. (Summer temperatures of barn air and their effect on milk performance of dairy cows, in Czech).

[CD-ROM]. In: MendelNet 2010 Proceedings of International Ph.D. Students Conference. s. 68. ISBN 978-80-7375-453-2.

ZEJDOVÁ, P., FALTA, D., CHLÁDEK, G., MÁCHAL, L., 2011: Effect of lactation stage, its number, current milk performance and barn air temperature on laterality of Holstein dairy cows laying behaviour. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis (5) 2011, s. 315–321. ISSN 1211-8516.

Address

Ing. Milan Večeřa, Ústav chovu a šlechtění zvířat, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, e-mail: milan.vecera@mendelu.cz