ELSEVIER

Livestock Production Science 77 (2002) 349–353

LIVESTOCK PRODUCTION SCIENCE

www.elsevier.com/locate/livprodsci

Short communication

Evaluation of naturally ventilated dairy barn management by a thermographic method

Ivana Knížková[a,*], Petr Kunc[a], Marie Koubková[b], Jan Flusser[c], Oldřich Dolezal[a]

[a]Research Institute of Animal Production, Prátelství 815, 104 00 Praha-Uhríněves, Czech Republic
[b]Czech University of Agriculture, Faculty of Agronomy, 165 21 Praha 6, Czech Republic
[c]Institute of Information and Automation, Academy of Sciences, 182 08 Praha 8, Czech Republic

Received 14 February 2001; received in revised form 20 February 2002; accepted 5 March 2002

Abstract

The goal was to assess the impact that human interventions in natural ventilation may have on microclimatic factors in a barn and on thermal comfort of dairy cows housed there. Thermal comfort of the cows in the barn was assessed from the changes in their body surface temperature. Microclimatic factors in the barn were modified by opening and closing sidewall plastic curtains in the barn and doors in alleys. While no changes in the body surface temperature were recorded when the air temperature dropped by 3.1 °C, a significant response ($P < 0.01$) was recorded when the air temperature dropped by 6.5 °C. Significant changes in the air velocity at temperatures within the thermoneutral range influenced thermal conditions in the barn, and significant changes in body surface temperatures caused by vascular responses ($P < 0.01$, $P < 0.05$) were recorded. It is impossible to assess thermal comfort of dairy cattle housed in barns objectively only on the basis of visually detectable thermoregulatory behaviour of the cows or of microclimatic parameters measured in barns, because different combinations of air temperatures and air velocities will result different intensity of body surface cooling. This is reflected in the variations of the body surface temperatures, which can be reliably monitored by thermography.

Keywords: Natural ventilation; Dairy cattle; Body surface temperature; Microclimatic factors; Infrared thermography

1. Introduction

From the point of view of barn ventilation management, spring and autumn are difficult periods of the year because of frequent significant changes in air temperature, relative humidity and air velocity. Practical management should take the needs of housed animals into account. The barn environment, however, also reflects the requirements of the people working there, and their requirements on thermal comfort are different from those of the cattle housed there. While the thermoneutral zone for cattle ranges from −5 to 25 °C (Hahn, 1999); the thermoneutral zone for people is shifted to higher air temperature ranges. This explains why barn workers will often interfere with proper ventilation management pat-

*Corresponding author. Tel.: +420-2-6771-1747; fax: +420-2-6771-0779.
E-mail address: knizkova@vuzv.cz (I. Knížková).

0301-6226/02/$ – see front matter
PII: S0301-6226(02)00062-3

terns in barns, and thus create an environment that is inadequate for the cattle (Meschner and Veenhuizen, 1998).

Barn ventilation is usually assessed by barn microclimate measurement methods based on the use of conventional measuring instruments. These methods cannot, however, define the immediate influences of microclimatic conditions on the housed animals. The body surface temperature measurements, on the other hand, can be used to assess the thermal comfort of cattle. The air temperature will trigger changes in the vascular circulation (vasodilatation or vasoconstriction), which is subsequently manifested as changes in the body surface temperature (Reece, 1998; Harper, 2000). A very high correlation has been ascertained between the body surface temperatures and the air temperature (Bukvaj, 1986; Chikamune, 1986). The studies of the influence of microclimatic conditions on the body surface temperature are, however, very few and data on this thermoregulatory function are scarce (Turnpenny et al., 2000). This is mainly because that function is difficult to measure. Hurnik (1984) recommended thermography to monitor body surface temperatures. Sensitive to temperature changes of 0.1 °C, this method can be used to generate a thermal profile of the entire body of the animal. Moreover, thermography is a non-invasive and safe method from the thermal profile visualization point of view (Speakmen and Ward, 1998; Cockroft et al., 2000).

The objective of our experiments was to monitor the influence of human interventions in natural ventilation on microclimatic factors in a dairy-cow barn, and on the thermal comfort of dairy cows housed there in spring.

2. Material and methods

In March and May, two experiments were made in a barn for 300 dairy cows with loose housing with cubicle beds and bedding. The barn featured an open sidewall with flexible plastic curtains to regulate the air flows in the barn, and a ridge opening.

In each experiment, 12 clinically healthy cows of the Czech Spotted breed in the first stage of lactation were used (number of lactation I–IV, average milk yield per year 4500 litres). Measurements were made 2 h after feeding.

The body surface temperature (BST) measurements were made by the thermographic camera AGA 570 DEMO with a 24 °C lens and automatic calibration. Individual thermograms were stored in the camera on the PCMCIA Camera Card 160 MB ATA. Air temperature (T) and relative humidity (RH) measurements were made by the digital thermometer TESTO 415, air velocity (V) by TESTO 615, and Canadian wind chill (CWC) was calculated from measurements made by Hill katathermometer. CWC calculates the wind chill as a heat loss in watts per square meter (Kreèmer, 1980).

Measurements were made over a period of 2 days in Experiment 1 (March) and Experiment 2 (May). Microclimatic factors were modified by opening and closing the plastic curtains of the sidewall openings and barn doors. Each open-and-closed cycle took 1 h. Thermographic measurements of the body surface temperature of individual cows standing in the feeding alley were taken in the last 20 min of each cycle at a distance of 3 meters. During thermographic measurements, air temperature, relative humidity, air velocity and wind chill were monitored.

Thermograms of dairy cows were analyzed using a special Irwin 5.3.1 computer software package developed exclusively for thermogram analysis. The software defined three areas on the bodies of the cows, i.e. the fore part (FP), the barrel (B) and the hind part (HP), and calculated average temperature levels in areas thus defined (mean±standard deviation (S.D.). The body surface temperature data were statistically processed by the t-Test for the significance of the difference between the means of two samples.

3. Results and discussion

3.1. Experiment 1 (March)

Detailed data on the changes in the body surface temperature in response to changed microclimatic conditions are given in Table 1. Air temperatures were within the thermoneutral zone for the cattle. A temperature drop of 3.1 °C (1st day, closed vs. open) within the range accompanied by minimum changes in other microclimatic factors failed to cause any significant vascular changes in the dairy cows tested, and their body surface temperatures remained practi-

Table 1
Changes of body surface temperature of dairy cows in relation to changes of microclimatic factors (March), mean and S.D. ($N = 12$)

	Cycles	T (°C)	RH (%)	V ($m \cdot s^{-1}$)	CWC ($W \cdot m^{-2}$)	FP (°C)	B (°C)	HP (°C)
1st day	Closed	16.6	48.2	0.08	195	31.02±1.22	30.22±0.97	30.33±0.80
	Open	13.5	53.1	0.12	462	30.90±1.20	30.30±1.21	30.43±0.72
Difference		− 3.1	+ 5.1	+ 0.04	+ 267	− 0.12	+ 0.10	+ 0.10
2nd day	Open	7.6	60	0.92	965	24.55±1.06	24.14±1.35	24.03±1.06
	Closed	10.0	61	0.17	383	27.52±1.23	27.07±1.43	27.51±1.01
Difference		2.4	+ 1	0.75	− 582	+ 2.97**	+ 2.93**	+ 3.48**
	Closed	10.0	61	0.17	383	27.52±1.23	27.07±1.43	27.51±1.01
	Open	8.5	54	0.84	965	24.11±1.09	23.83±1,57	23.61±1.32
Difference		− 1.5	− 7	+ 0.67	+ 582	− 3.41**	− 3.24**	− 3.90**

**, $P < 0.01$. T, air temperature; RH, relative humidity; V, air velocity; CWC, Canadian wind chill; FR, fore part; B, barrel; HP, hind part.

cally the same. A significant decrease and increase in air velocity in combination with minimum changes in air temperature and relative humidity (2nd day, open vs. closed and closed vs. open), however, did trigger a significant response in their body surface temperatures, and significant changes ($P < 0.01$) were found in all three areas investigated (FP, B and HP). No statistically significant changes between the three areas were, however, ascertained. The CWC score rated the wide-open barn as very cold.

3.2. Experiment 2 (May)

Detailed data on the changes in the body surface temperature in response to changed microclimatic conditions are given in Table 2. A temperature drop of 6.5 °C from 22.7 to 16.2 °C (1st day, closed vs. open) in combination with minimum changes in other microclimatic factors caused significant changes in the body surface temperature ($P < 0.05$). On the second day of the experiment, air temperatures were at the upper limit of the thermoneutral zone, and the barn environment was very hot to sultry. Higher air velocities in the barn (2nd day, open vs. closed and closed vs. open) at those temperatures caused significant changes in the body surface temperature of the dairy cows monitored ($P < 0.01$ for HP, $P < 0.05$ for FP and B). A comparison between temperature changes in Experiment 1 (March) and the Experiment 2 (May), however, showed that changes in the body surface temperature in Experiment 2 (May) were smaller.

The body surface temperature depends on the air temperature (Terui et al., 1984; Chikamune, 1986;

Table 2
Changes of body surface temperature of dairy cows in relation to changes of microclimatic factors (May), mean and Sd ($N = 12$)

	Cycles	T (°C)	RH (%)	V ($m \cdot s^{-1}$)	CWC ($W \cdot m^{-2}$)	FP (°C)	B (°C)	HP (°C)
1st day	Closed	22.7	68	0.10	156	33.42±0.52	33.34±0.66	33.18±0.58
	Open	16.2	66.5	0.35	346	31.86±0.86	31.91±1.13	31.36±1.02
Difference		− 6.5	− 1.5	+ 0.25	+ 190	− 1.56*	− 1.43*	− 1.82*
2nd day	Open	21.7	49	1.75	336	31.38±0,64	31.11±0.93	31.04±0.73
	Closed	25.2	52	0.08	142	31.85±0.66	32.03±0.73	32.08±1.31
Difference		+ 3.5	+ 3	− 1.67	− 194	+ 0.48*	+ 0.92*	+ 1.03*
	Closed	25.2	52	0.08	142	31.85±0,66	32.03±0.73	32.08±1.31
	Open	24.4	46.5	2.00	432	31.37±1.05	31.36±1.23	31.22±1.32
Difference		− 0.8	− 5.5	+ 1.93	+ 290	− 0.48*	− 0.67*	− 0.85**

*, $P < 0.05$; **, $P < 0.01$. T, air temperature; RH, relative humidity; V, air velocity; CWC, Canadian wind chill; FR, fore part; B, barrel; HP, hind part.

Gerken et al., 1998). It may, however, be significantly influenced by other microclimatic factors as well. In the present study, the authors changed the air velocity in the barn, which greatly influenced thermal conditions there. When the air temperature was within the thermoneutral range, dairy cows responded to an excessive increase in air velocity by reducing their heat losses, which was manifested by a significant vascular response and changes in the body surface temperature. The subsequent decrease in air velocity, on the other hand, made the cows increase their heat losses, which was manifested by a change in their body surface temperatures. These findings correspond with results reported by Bukvaj (1986) and Olson (1984), because a change in thermal conditions will promptly trigger a vascular response in the skin that will result in a higher or lower heat losses of the individual.

Smaller changes in the body surface temperature in Experiment 2 (May) were due to air temperatures at that time. Temperatures in the range from 16.2 to 25.2 °C are at the extreme end of the thermoneutral zone and close to a thermal stress situation for cattle (Hahn, 1999; Koga et al., 1999). At those air temperatures, vascular responses are less pronounced than at lower temperatures, and their possibilities to provide for heat losses are restricted. At that time, increased air velocity is particularly desirable because it produces a cooling effect and reduces the thermal stress (Bucklin et al., 1988; Dolejš et al., 2000).

The response in all three body areas monitored, i.e. fore part, barrel and hind part, was practically the same, and insignificantly bigger changes were found in the hind part only. As measurements of entire cows showed, it is not possible to recommend any one specific limited area as the optimum spot for the measurements of thermal comfort. In their study, Knížková et al. (1996) demonstrated that the body surface temperature distribution in dairy cows is very variable. Measurements taken in a single spot may be particularly inaccurate.

4. Conclusion

It is impossible to assess thermal comfort of dairy cattle housed in barns objectively only on the basis of visually detectable thermoregulatory behaviour of the cows or of microclimatic parameters measured in barns, because different combinations of air temperatures and air velocities will result different intensity of body surface cooling. This is reflected in the variations of the body surface temperatures, which can be reliably monitored by thermography.

Acknowledgements

The work was supported by project No. 523/99/1489 of the Grant Agency of Czech Republic.

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