# Impact of the location of the dairy cows in the barn on their body surface temperature

# Vliv umístění dojnic ve stáji na teplotu povrchu těla

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## Abstract

The objective of the study was to determine skin surface temperature of dairy cows housed in tie stalls, according to their location in the barn. A total of 52 healthy cows were investigated, 31 of which were kept in "cold" stalls by the entrance to the barn and 21 in "warm" stalls located in the centre of the barn. Skin surface temperature was measured in 8 different body parts using a non-contact thermometer (Fluke 572 pyrometer). The results showed that skin temperature of the cows varied according to their location. It was significantly lower in the cows housed in "cold" stalls compared to those kept in "warm" stalls ($P < 0.05$). The difference was particularly evident for the udder, reaching 1.1°C ($P < 0.01$). Skin temperature of the cows varied between different measurement points. In both "cold" and "warm" stalls, skin temperature was highest on the udder and lowest at the hock joint ($P < 0.01$). Time of day and air temperature outside the barn had a highly significant effect on the skin temperature of the cows. The lower the air temperature was, the lower was the skin temperature at all points of measurement ($P < 0.01$). It was found that the skin surface of housed cows subjected to increased air movement is at a greater risk of becoming hypothermic.

**Keywords:** body surface temperature, dairy cows, housing system, welfare

## Abstrakt

Cílem této studie bylo stanovit vliv umístění dojnic ve vazné stáji na jejich teplotu povrchu těla. Celkem bylo sledováno 52 dojnic, z nichž 31 bylo umístěno blízko vchodu do stáje („chladné" kotce) a 21 v centru stáje („teplé" kotce). Teplota kůže byla měřena na osmi místech na těle dojnic pomocí bezdotykového teploměru (Fluke 572). Výsledky ukázaly, že umístění dojnic mělo vliv na jejich teplotu povrchu těla. Teplota kůže byla významně nižší v chladných kotcích než v teplých kotcích (P <

0,05). Rozdíl byl patrný především u vemene, kde dosahoval 1,1°C (P < 0,01). Teplota se lišila také mezi jednotlivými měřenými částmi těla: nejvyšší byla na vemenu a nejnižší na hleznu (P < 0,01). Na teplotu kůže měla statisticky významný vliv také denní doba a venkovní teplota vzduchu. S vyšší teplotou vzduchu se zvyšovala také teplota kůže na všech sledovaných částech těla (P < 0,01). Z výsledků vyplynulo, že kůže ustájených krav vystavených zvýšenému kolísání teploty vzduchu je více ohrožena podchlazením.

**Klíčová slova:** dojnice, systém ustájení, teplota povrchu těla, welfare

## Detailed abstract

Teplota uvnitř stájí je jedním z faktorů, jež určují pohodu ustájených dojnic a významně se projevují na produkčních i zdravotních výsledcích chovu. Nabývá na významu především v chovech, kde je dosud uplatňován vazný způsob ustájení. Využití bezkontaktních teploměrů při měření teploty povrchu zvířat nabízí levný způsob sledování teploty různých částí těla v závislosti na umístění zvířat ve stáji nebo v závislosti na roční nebo denní době a venkovní teplotě. Cílem této studie bylo určit, jak se projevuje umístění dojnic v rámci stáje na povrchovou teplotu těla v závislosti na zmíněných faktorech. Celkem bylo sledováno 52 dojnic, z nichž 31 bylo umístěno blízko vchodu do stáje („chladné“ kotce) a 21 v centru stáje („teplé“ kotce). Jednalo se o černostrakatý skot s více jak 50% podílem plemene Holštýn. Dojnice byly v dobré zdravotní kondici, v laktaci a jejich průměrná dojivost byla 6695 kg mléka na laktaci. Teplota kůže byla měřena na osmi místech na těle dojnic pomocí bezdotykového teploměru (Fluke 572). Teplota byla měřena dvakrát denně: ráno v 8.00 a večer v 17.00. Navíc byl sledován pohyb vzduchu uvnitř stáje a vlhkost vzduchu. Pro statistickou analýzu dat byly využity obecné lineární modely (GLM) a post-hoc Scheffe test v rámci programu Statistica ver. 7.1. V analýze bylo využito následujícího modelu: $Y_{ijklm} = \mu + P_i + T_j + S_k + Z_{kl} + \epsilon_{ijklm}$ ,kde: μ – střední hodnota; $P_i$ – efekt denní doby (ráno, večer); $T_j$ – efekt venkovní teploty vzduchu (1-9°C, 10-19°C, nad 19°C); $S_k$ – efekt kotce (teplý, studený); $Z_{kl}$ – efekt zvířete; $\epsilon_{ijklm}$ – náhodná chyba. Navíc pro studené a teplé kotce zvlášť byl proveden výpočet analýzou variance (ANOVA), opět v rámci statistického programu Statistica ver. 7.1. Využit byl následující model: $Y_{ij} = \mu + O_i + \epsilon_{ij}$ ,kde: μ – střední hodnota; $O_i$ – efekt teploty na měřenou část těla; $\epsilon_{ij}$ – náhodná chyba. Výsledky ukázaly, že umístění dojnic mělo statisticky průkazný vliv na jejich teplotu povrchu těla. Teplota kůže byla významně nižší v chladných kotcích než v teplých kotcích (Tab. 2; P < 0,05). Rozdíl byl patrný především u vemene, kde dosahoval 1,1°C (Tab. 3, 4; P < 0,01). Teplota se lišila také mezi jednotlivými měřenými částmi těla: nejvyšší byla na vemenu a nejnižší na hleznu (Tab. 3, 4; P < 0,01). Na teplotu kůže měla statisticky významný vliv také denní doba (Tab. 5) a venkovní teplota vzduchu (Tab. 6). S vyšší teplotou vzduchu se zvyšovala také teplota kůže na všech sledovaných částech těla (Tab. 6; P < 0,01). Z výsledků vyplynulo, že kůže ustájených krav vystavených zvýšenému kolísání teploty vzduchu je více ohrožena podchlazením. To se projevilo především u vemene. Teplota vemene se zvyšuje během dojení (Janeczek, a kol., 1995; Paulrud, a kol., 2005) a po dojení se stává kůže vemene velmi citlivá k podchlazení (Janeczek, a kol, 1995). Tato citlivost bývá větší především u dojnic v počáteční fázi laktace. Vemena, která jsou vystavena podchlazení bezprostředně po dojení jsou navíc vice náchylná k zánětům. Rozdíly v teplotě jednotlivých částí těla zaznamenali take jiní autoři.

Vyšší teplotu na povrchu vemene oproti hleznu zaznamenal například také Kwaśnicki a kol. (2007). Tyto poznatky mohou pomoci chovatelům se zavedením preventivních opatření na zvýšení pohody chovaných zvířat a k dosažení lepších produkčních a zdravotních ukazatelů chovu.

## Introduction

Breeders of livestock, including dairy cows, are becoming increasingly aware of the relationship between animal welfare, health and productivity (Bartussek, et al., 2000; Anonymus, 2001; Phillips, 2002; Brouček, et al., 2008; von Keyserlingk et al., 2009). One of the welfare requirements is to avoid the thermal discomfort. The milk production is reduced by the heat stress and has a negative impact on the effectivity of the cattle breeding (Kadzere, et al., 2002; Silanikove, 1992). In the interaction between the external environment and the animal body, the skin and the hair coat act as a buffer layer (Jodkowska, 2000). Rather than being uniform all over the surface, skin temperature varies by several degrees depending on the body area and the exposure to thermal stimuli from the environment (Jodkowska, et al., 2001).
Thermal discomfort of cows has been the subject of many studies, most often with regard to the effect of heat stress on the cow’s body (Šoch et al., 2003; Brouček, et al., 2009; Dikmen, et al., 2008; Dikmen and Hansen, 2009; Silvestre, et al., 2009). Thermal comfort of the cows housed indoors from autumn to spring is an equally important issue as heat stress. This particularly concerns the tie-stall system in which the cows have restricted freedom of movement and are, in a way, assigned to a stall (Spiers, et al., 2004; Zähner, et al., 2004; Šoch, 2005).
In most leading cattle breeding countries, loose housing is the dominant housing system for dairy cows. However, in some countries (such as Poland), cows are still housed in tie stalls if the scale of production is smaller (Frelich, et al., 2009; Nawrocki, 2009; Szarek, et al., 1998).
The exposure of the skin surface of tie stall cows to thermal environmental stimuli depends on the type of stall and its location within the barn. Cows kept in stalls near the door and in areas with increased air movement may suffer from hypothermia. This, in turn, may negatively affect skin surface temperature in some body areas, e.g. the udders. It should be remembered that the mammary gland is very sensitive to microclimate conditions, especially immediately after milking (Janeczek, et al., 1995).
The skin temperature of animals has recently come to be measured with thermography based devices, including thermovision cameras (Colak, et al., 2008; Hovinen, et al., 2008). The cost of this equipment is not insignificant. Less expensive equipment, e.g. pyrometers, can be used for non-contact measurement of temperature.
The aim of this study was to determine the skin temperature of the cows housed in tie stalls, according to their location within the barn.

## Materials and methods

The study involved 52 Black-and-White hybrid cattle with a considerable (>50%) percentage of Holstein-Friesian breeding. The cows were healthy, lactating, and their yield averaged 6,695 kg of milk per lactation. The investigated cows were kept on litter in a flat barn with tie stalls. The stalls (1.7 m x 1.1 m) were arranged in four

rows. Skin temperature was measured in “cold” stalls in 31 of the cows and in “warm” stalls in 21 of the cows.
Stalls were chosen mainly on the basis of their location within the barn. “Cold” stalls were located in the immediate vicinity of the door and “warm” stalls were situated in the centre of the barn. The numerical values of the microclimate parameters are given in Table 1. Air movement was almost three times greater in “cold” stalls than in “warm” stalls. Cooling power was higher in “cold” stalls, and relative air humidity in “warm” stalls.

Table 1. Mean values of microclimate measurements

| Item | Cold stalls | Warm stalls |
|---|---|---|
| Cooling power ($W/m^2$) | 41.42 | 30.51 |
| Air movement (m/s) | 0.237 | 0.090 |
| Relative humidity (%) | 48.22 | 56.11 |

Skin temperature was measured with a non-contact thermometer (*Fluke 572 pyrometer*). The following eight points were measured on the cow’s body:
- left and right sides of the chest behind the shoulder,
- left and right sides of the rump at the level of the hip joint,
- left and right hock joints,
- front and back of the udder.

Body temperature was measured in the morning (08:00) and in the evening (17:00) on 12-15 September 2006 and on 12-19 October 2006. On the days on which skin temperature was determined, air temperature outside the barn was measured using a mercury thermometer, and cooling power, air movement and relative humidity were measured in the experimental stalls. Cooling power and air movement were measured using Hill’s dry kata-thermometer, and air humidity with Assmann’s aspiration psychrometer.
The data were analysed statistically using the GLM procedure according to the following model:
$Y_{ijklm} = \mu + P_i + T_j + S_k + Z_{kl} + \epsilon_{ijklm}$
where: μ – overall mean; $P_i$ – effect of $i^{th}$ time of day (morning, evening); $T_j$ – effect of $j^{th}$ atmospheric temperature (1-9°C, 10-19°C, above 19°C); $S_k$ – effect of $k^{th}$ stall (warm, cold); $Z_{kl}$ – effect of $k^{th}$ animal within $l^{th}$ stall; $\epsilon_{ijklm}$ – random error
In addition, analysis of variance was performed separately for “warm” and “cold” stalls according to the following model:
$Y_{ij} = \mu + O_i + \epsilon_{ij}$
where: μ – overall mean; $P_i$ – effect of $i^{th}$ temperature in the cow’s body area (left side of the chest, left side of the rump, left hock joint, front of the udder, back of the udder, right side of the chest, right side of the rump, right hock joint); $\epsilon_{ij}$ – random error
Significant differences between the means were analysed using Scheffe’s test. Calculations were made using Statistica ver. 7.1.

## Results

The skin temperature of the cows kept in “cold” stalls was highly significantly different from that of the cows housed in “warm” stalls for all measurement points except the right hock joint (Table 2). The highest temperature difference (1.1°C) was found for the front of the udder and the lowest (0.3°C) for the right hock joint.

Table 2. Skin temperature (°C) of the cows according to the stall

| Body area | Stalls[a] | | Significance of differences[b] |
|---|---|---|---|
| | Cold (N=216) | Warm (N=144) | |
| Left side of the chest | 31.4 ±2.14 | 32.2 ±1.67 | ** |
| Right side of the chest | 31.5 ±1.99 | 32.3 ±1.70 | ** |
| Left side of the rump | 31.9 ±2.31 | 32.7 ±1.52 | ** |
| Right side of the rump | 32.1 ±2.06 | 32.7 ±1.92 | ** |
| Left hock joint | 30.6 ±2.38 | 31.4 ±1.77 | ** |
| Right hock joint | 31.1 ±2.26 | 31.4 ±1.95 | * |
| Front of the udder | 33.6 ±1.85 | 34.7 ±1.34 | ** |
| Back of the udder | 33.9 ±1.60 | 34.4 ±1.15 | ** |

[a] numerical values represent the mean ± standard deviation;
[b] * – means in a row differ at $P < 0.05$; ** – means in a row differ at $P < 0.01$

Within "cold" stalls, skin temperature differed highly significantly between individual measurement points (Table 3). The highest temperature (33.9°C) was noted for the back of the udder and the lowest (30.6°C) for the left hock joint ($P < 0.01$).

Table 3. Skin temperature (°C) of the cows in cold stalls

| Body area | Mean[a] | SD |
|---|---|---|
| N=216 | | |
| Left side of the chest | $31.4^{ABCD}$ | 2.14 |
| Right side of the chest | $31.5^{NPTWZ}$ | 1.99 |
| Left side of the rump | $31.9^{EFGH}$ | 2.31 |
| Right side of the rump | $32.1^{DLORUW}$ | 2.06 |
| Left hock joint | $30.6^{AEIJMNO}$ | 2.38 |
| Right hock joint | $31.1^{HLSVZ}$ | 2.26 |
| Front of the udder | $33.6^{BFIPRS}$ | 1.85 |
| Back of the udder | $33.9^{CFJMTUV}$ | 1.60 |

[a] mean values marked with the same capital letters (ABC...) differ at $P < 0.01$

Similarly, skin temperature of the cows in "warm" stalls differed highly significantly between individual measurement points (Table 4). It was the highest for the front of the udder (34.7°C) and the lowest (31.4°C) for the left and right hock joints ($P < 0.01$).

Table 4. Skin temperature (°C) of the cows in warm stalls

| Body area | Mean[a] | SD |
|---|---|---|
| N=144 | | |
| Left side of the chest | $32.2^{ABCD}$ | 1.67 |
| Right side of the chest | $32.3^{KNRU}$ | 1.70 |
| Left side of the rump | $32.7^{EFGH}$ | 1.52 |
| Right side of the rump | $32.7^{MOSV}$ | 1.92 |
| Left hock joint | $31.4^{AEIJKM}$ | 1.77 |
| Right hock joint | $31.4^{DHPTUV}$ | 1.95 |
| Front of the udder | $34.7^{BFINOP}$ | 1.34 |
| Back of the udder | $34.4^{CGJRST}$ | 1.15 |

[a] mean values marked with the same capital letters (ABC...) differ at P < 0.01

In general, the standard deviation was higher for skin temperature measurements of the cows in “cold” stalls (Table 3) compared to “warm” stalls (Table 4).
The time of measurement had a highly significant effect on the skin temperature of the cows. It was higher in the evening at all measurement points (Table 5) (P < 0.01). The lowest differences between the morning and evening temperatures were found for udder skin.

Table 5. Effect of time of day on skin temperature ($^{o}$C) of the cows

| Body area | Time of day[a] | | Significance of differences[b] |
|---|---|---|---|
| | Morning (N=180) | Evening (N=180) | |
| Left side of the chest | 31.2 ±2.24 | 32.3 ±1.55 | ** |
| Right side of the chest | 31.1 ±2.03 | 32.5 ±1.49 | ** |
| Left side of the rump | 31.6 ±2.31 | 32.9 ±1.53 | ** |
| Right side of the rump | 31.7 ±2.24 | 33.0 ±1.52 | ** |
| Left hock joint | 30.3 ±2.31 | 31.7 ±1.82 | ** |
| Right hock joint | 30.7 ±2.42 | 31.7 ±1.68 | ** |
| Front of the udder | 33.7 ±1.90 | 34.4 ±1.49 | ** |
| Back of the udder | 33.7 ±1.57 | 34.5 ±1.23 | ** |

[a] numerical values represent the mean ± standard deviation;
[b] ** – means in a row differ at P < 0.01

There was also a highly significant effect of atmospheric temperature outside the barn on the skin temperature of the cows (Table 6). During the study, air temperature outside the barn averaged 16°C in September and 4.5°C in October. With increasing atmospheric temperature, the skin temperature of the cows increased at all measurement points. The area of the body that responded the least to changes in atmospheric temperature was the udder.

Table 6. Effect of atmospheric temperature ($^{o}$C) outside the barn on skin temperature of the cows

| Body area | Atmospheric temperature (°C)[a] | | |
|---|---|---|---|
| | 0-9 (N=60) | 10-19 (N=180) | > 19 (N=120) |
| Left side of the chest | $28.9^{AB}$ ±1.79 | $31.9^{AC}$ ±1.50 | $32.9^{BC}$ ±1.23 |
| Right side of the chest | $29.0^{AB}$ ±1.75 | $31.9^{AC}$ ±1.26 | $33.1^{BC}$ ±1.24 |
| Left side of the rump | $29.4^{AB}$ ±2.28 | $32.4^{AC}$ ±1.49 | $33.5^{BC}$ ±1.16 |
| Right side of the rump | $29.3^{AB}$ ±1.92 | $32.5^{AC}$ ±1.33 | $33.7^{BC}$ ±1.20 |
| Left hock joint | $28.3^{AB}$ ±2.14 | $30.9^{AC}$ ±1.70 | $32.4^{BC}$ ±1.54 |
| Right hock joint | $28.5^{AB}$ ±2.08 | $31.2^{AC}$ ±1.81 | $32.5^{BC}$ ±1.19 |
| Front of the udder | $32.6^{AB}$ ±1.98 | $34.1^{AC}$ ±1.61 | $34.8^{BC}$ ±1.33 |
| Back of the udder | $32.6^{AB}$ ±1.75 | $34.2^{AC}$ ±1.25 | $34.7^{BC}$ ±1.05 |

[a] numerical values represent the mean ± standard deviation; mean values marked with the same capital letters (ABC...) differ at P < 0.01

## Discussion

The results obtained showed that skin temperature of the experimental cows varied according to their location. It was significantly lower in the cows kept in stalls in the

immediate vicinity of the door, compared to the cows housed in stalls in the centre of the barn.
It has been accepted that air velocity in the buildings for cows should not exceed 0.2-0.5 $m*s^{-1}$ (Anonymus, 2001). Air velocity in “cold” stalls (0.237 $m*s^{-1}$) did not exceed the upper acceptable limit of 0.5 m/s, but was considerably higher than in “warm” stalls (0.09 $m*s^{-1}$), which possibly contributed to the greater hypothermia of the skin surface in the cows kept in “cold” stalls.
This was particularly noticeable for the udder. Skin temperature on the front of the udder was 1.1°C lower in cows kept in “cold” stalls compared to those housed in “warm” stalls. Udder skin temperature increases during milking (Janeczek, et al., 1995; Paulrud, et al., 2005). Immediately after milking, udder skin becomes highly sensitive to hypothermia (Janeczek, et al., 1995). This sensitivity may be greater in cows in the first stage of lactation. Schmidt et al. (2004) reported higher udder skin temperature in late lactation compared to early lactation cows, both before and after milking.
The udders of the cows exposed to excessive hypothermia immediately after milking may be more susceptible to rheumatic inflammations. The skin temperature of the analysed cows differed between individual measurement points. Within both “cold” and “warm” stalls, skin temperature was the highest on the udder and the lowest on hock joints.
Higher blood flow to the udder compared to the hock joints must have been responsible for the differences in the skin temperature of the body parts mentioned above. Kwaśnicki et al. (2007) also reported that udder skin temperature was considerably higher compared to hock joints and knees. The effect of side of the body on the skin temperature of the analysed cows seems hard to interpret. In our study, we found higher skin temperature on the right side of the body but only within “cold” stalls. On the other hand, Kwaśnicki et al. (2007) reported much higher skin temperature in respective measurement points on the left side of the cow’s body.
The effect of time of day on the skin temperature of the cows was understandable. It was higher in the evening. Skin temperature is the consequence of the whole body temperature, which is generally higher during the evening hours compared to the morning hours. In a study by Gil (1982), cow’s body temperature was higher by an average of 0.11°C in the evening compared to the morning hours.
In our study, we also found that air temperature outside the barn had a highly significant effect on the skin temperature of the cows. These measurements, taken in September and October, revealed no dramatic declines in air temperature, or its increases above 25°C. The lower the air temperature, the lower the skin temperature of the cows was at all measurement points, although this decrease in skin surface temperature was the lowest in the case of the udder.

## Conclusions

In conclusion, the skin surface temperature of the cows housed in the tie-stall system may vary according to the cows’ location within the barn. The skin surface of the cows housed in stalls subject to increased air movement was found to be at a greater risk of becoming hypothermic. This should be borne in mind, especially with regard to the udder, which reacts the most to draughts. These relationships between skin surface temperature of the cows and their location in the barn may be particularly noticeable with decreasing air temperature. Knowledge of the results of this study will enable dairy breeders to give more attention to the welfare of cows in the context of their thermal comfort. The elimination of drafts in the barn may contribute, among others, to reducing the risk of rheumatic mastitis in cows. The results of the present study should also be of interest to designers of livestock buildings for dairy cows.

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