Contact and non-contact thermometry in the milk acquisition process

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ABSTRACT: Temperatures of the northern wall, ceiling and floor of a 2 × 12 milking house as well as of a waiting area in front of the milking house were measured for 24 hours a day in the winter season with an average external daily temperature of –8.6°C. The influence of low external temperatures on the temperatures of cows' mammary glands was measured with a non-contact thermometer RAYNGER ST 6 equipped with laser. The analysis showed that the low external temperatures and insufficiently warmed external walls [average 24-hour temperatures: (t_{st} = +1.32°C), ceiling (t_s = +2.65°C), floor (t_p = +3.29°C)] as well as the waiting area in front of the milking house (t_d = +1.9°C) produced unsuitable temperature conditions despite of the use of heaters in the milking house, resulting in the undercooling of mammary glands and the traumatising of dairy cows. The temperatures of mammary glands of tested dairy cows were evaluated by a multifactor analysis of variance. The time and place of measuring were statistically significant on the significance level 0.05. The *F*-test value for the factor of time was 12.342, with probability 0.0007. The *F*-test value for the place of temperature measuring was 1061.979, probability 0.0000. Among the equations of curves of the dependences of teat end temperature on the milking time, the closest seemed to be the logarithmic function with determination index R^2 = 0.7404.

Keywords: temperatures; non-contact thermometer; mammary gland; milking house

The milking of cows in milking houses is carried out under different conditions than in stables. As for the milking house, the emphasis should be laid especially on the stabling, milking house type, milking technology, observation of daily routine, sociological, psychic and ethological singularities of cows. Furthermore, there are problems related to the influence of cow waiting in front of the milking house, influence of climatic conditions and their changes (temperature changes) as well as the influence of new conditioned reflexes (Kadlec, 1961). Recent research shows that milking was improved especially by the influence of construction elements, which was verified under laboratory and operational conditions by many researches (Groda, 1984; Přikryl, 1989; Karas, 1996; Gálik, 2001, Tančin *et al*., 2001).

The technological equipment of milking houses is closely related to their construction part. As Hejlíček *et al*. (1987) reported, the disposing moments were necessary for the origin of mastitis caused by *E. coli*, including the traumatising of cows by weather changes, especially by the undercooling of the mammary gland. The temperature mode in the stable is affected by the losses of temperature through the external wall, roof construction and floor. The temperature-technical quality of the floor is basically determined by the treading layer. Lendelová *et al*. (2002), Pogran (2000) stated that the final design of the floor construction is a summary of processed information about how to secure the most suitable temperature conditions for animals, with regard to the results of preference floor tests.

Kejík and Mašková (l989) pointed out that one of the possibilities how to determine the response of the organism to milking conditions is to use thermovision, measuring surface temperatures of the udder during milking.

For physiological research and temperature calculations for stables, two methods of determining the amount of heat emanated by animals to the environment are applied: (1) the overall production of temperature by animals is measured by means of calorimetry in special air-conditioned boxes, (2) the overall production of temperature is determined on the basis of the total energetic balance (Draganov, 1989). The latter method requires to know radiation, convectional elements (by flowing) of temperature production as well as the amount of temperature conducted by animal limbs.

MATERIAL AND METHODS

The analysis of temperatures and relative humidity was carried out under operational conditions in a 2 × 12 milking house during the winter season (25–26 January 2001). In the time of the analysis there were 548 dairy cows on the farm. Average annual production was 6 200 litres of milk per cow.

The following parameters were monitored in the milking house during 24 hours in one-hour intervals, using a non-contact thermometer RAYNGER ST 3 with laser:

– temperature of the northern interior wall of the milking house at a height of 1.80 m from the ground (°C)
– temperature of the interior roof part of the milking house (°C)
– temperature of the milking house floor (°C)
– temperature of the mammary gland after washing (°C)
– temperature of udders before and after milking (°C)
– temperature of teats at the base before and after milking (°C)
– temperature of teats in the middle part before and after milking (°C)
– temperature of teats at the end before and after milking (°C)
– time of milking of the experimental cow group (min)

Technical data: Raynger ST-6, enlarged model of laser

– temperature range: –32º to 500°C
– accuracy: ± 1% of reading or ± 1°C, whichever is greater
– response time: 500 ms (95% response)
– spectral response: 7–18 μm nominal, thermopile detector
– emissivity: 0.3–1.0 digitally adjustable
– temperature display: 4 digit LCD

The analysis of the mammary gland temperature assessment before and after milking was carried out in the whole group, i.e. 12 cows. In all cases, temperatures were measured on the left rear teats.

Additional monitored parameters of the analysis – external temperature, waiting area temperature and temperature in the milking house as well as relative humidity – external, in the waiting area in front of the milking house and in the inside of the milking house – were measured by means of digital thermometers and humidity meters during 24 hours in one-hour intervals.

Non-contact measuring of temperatures of different objects and materials is based on the principle of energy radiation in the invisible infrared spectrum. The volume of emitted energy is proportionate to the temperature and "emissivity" of the object. The emissivity depends on the material from which the object is made and on its surface adjustment. The quality of emission and reflection of the material is determined by the emissivity that can reach the values from 0.30 to 1.00.

Infrared devices allow to measure temperatures by the scanning of total energy emanating from the target object which consists of emitted, reflected, and transferred energy (Figure 1).

Using the given emissivity values the thermometer counts emitted energy and compensates for the influence of reflected energy. The temperature is then calculated from the volume of emitted energy. It is possible to read out the final temperature on the display of the device almost immediately.

RESULTS

Figure 2 shows the graphical course of temperatures and humidity measured in one-hour intervals during 24 hours outside, in the waiting area in front of the milking house, and in the milking house by means of contact and non-contact technology.

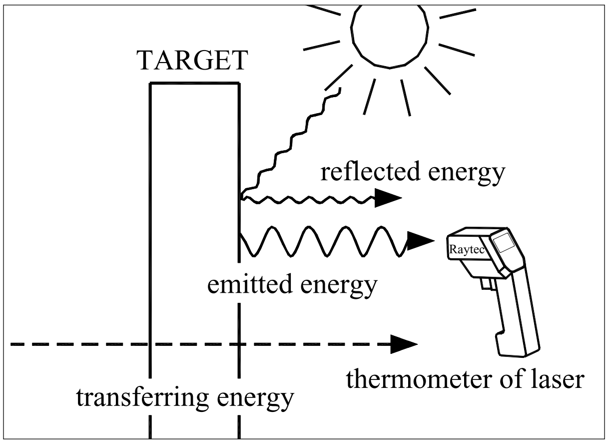

Figure 1. Non-contact thermometer RAYNGER ST 3 with laser – principle of operation

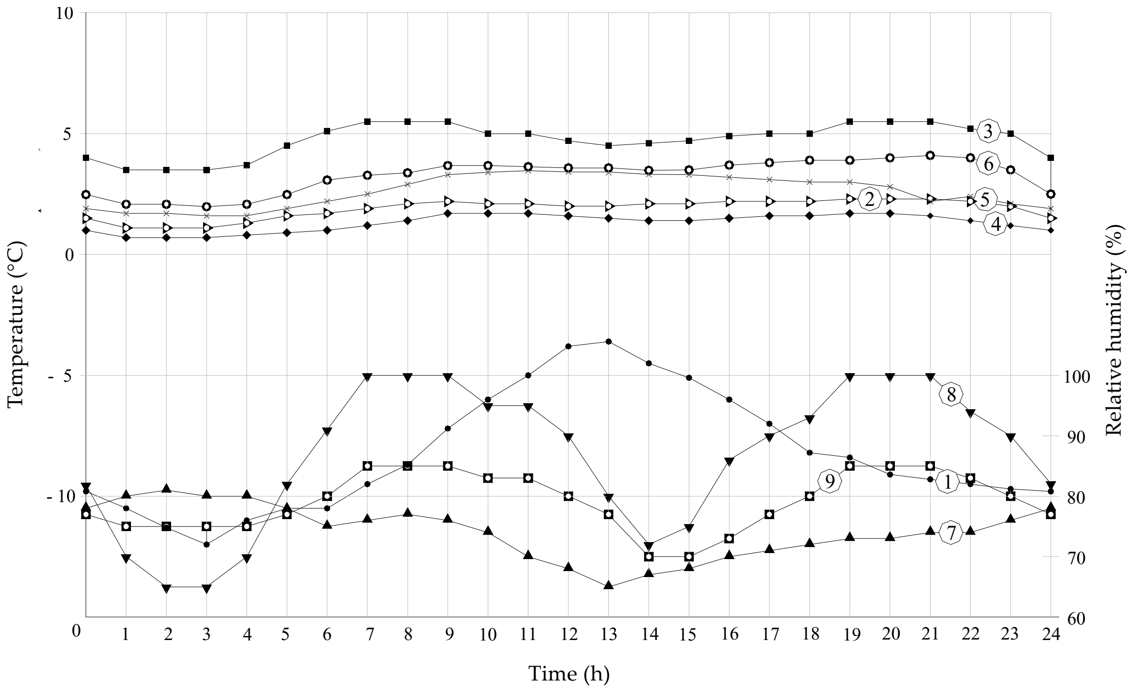

Figure 2. Temperatures and relative humidity values outside, in the waiting area and in the milking house during 24-hour analysis in the winter season

① external air temperature; ② waiting area air temperature; ③ milking house air temperature (on the mammary gland level); ④ surface temperature of the milking house interior wall (180 cm from the ground); ⑤ surface temperature of the milking house ceiling; ⑥ surface temperature of the milking house floor; ⑦ external air relative humidity; ⑧ relative humidity in the milking house (on the mammary gland level); ⑨ relative humidity in the waiting area

Low average daily external temperature (–8.6°C) and insufficient heat-insulating qualities of the external walls and ceiling as well as low efficiency of heating bodies in the milking house caused low average temperatures not only in the milking house (+4.76°C) but also in the waiting area in front of the milking house (+1.9°C). Table 1 shows that average internal temperatures of the wall (+1.32°C), ceiling (+2.65°C), floor (+3.29°C), as well as high average humidity in the milking house (86.8%) caused that especially temperature conditions significantly lagged behind the optimal standards set for milking houses (12–15°C).

Mammary gland temperatures were determined before and after milking, already under the above conditions in the milking house according to Figure 3 with a non-contact thermometer with laser.

Basic statistical processing of measured temperature values of mammary gland before and after milking is shown in Table 2. The highest average temperature before milking was measured on udders (30.14°C), at the base (29.55°C) and in the middle part (28.59°C); the lowest one was measured at teat ends (7.1°C). After milking, the temperature on the udder increased on average by 0.31°C, at the base by 0.82°C, in the middle part of the teat by 1.47°C and at teat ends by 2.68°C.

The mammary gland temperatures before and after milking were further processed by multifactor analysis of variance, using STATGRAPHICS 5.0 programme. Two factors were examined: the first factor was time, on two levels, before and after milking; the second factor was the place of temperature measurement on the mammary gland (time and place of measurement affect temperature values). The *F*-test analysis of variance value for the factor of time was 12.342, with signification (*P*-value, probability) of 0.0007. For the place of measurement the *F*-test value reached 1 061.979 and signification 0.0000. The test of time contrasts (differences within a group) was carried out by means of Scheffe test on the significance level of 0.95.

Table 1. Basic statistical assessment of temperatures and relative humidity during 24-hour analysis

Statistical value	Temperatures (°C)						Relative humidity (%)		
	external	waiting area	milking house	milking house wall	milking house ceiling	milking house floor	external	waiting area	milking house
$\bar{x}$	–8.6	+1.9	+4.7	+1.3	+2.6	+3.2	74.0	79.2	86.8
Max.	–12.0	+2.3	+5.5	+1.7	+3.5	+4.1	81.0	85.0	100.0
Min.	–3.6	+1.1	+3.5	+0.7	+1.6	+2.1	65.0	75.0	65.0
s	2.505	0.402	0.676	0.358	0.688	0.680	4.472	4.869	11.969
v	30.652	21.147	14.197	27.158	25.936	20.714	6.043	6.150	13.786

$\bar{x}$ = arithmetic mean max – maximal value in the set; *s* = decisive min – minimal value in the set; *v* = coefficient of variation

Table 2. Basic statistical assessment of measured temperatures of mammary gland

Place of measurement	Winter season – temperatures (°C)									
	Before milking – statistical value					After milking – statistical value				
	$\bar{x}$	max.	min.	*s*	*v*	$\bar{x}$	max.	min.	*s*	*v*
Udder	30.1	31.3	28.6	0.919	3.048	30.4	32.1	28.7	1.302	4.276
Teats: at base	29.5	30.8	28.3	0.903	3.055	30.3	31.3	28.8	0.806	2.656
in the middle part	27.1	29.8	27.3	0.889	3.112	28.5	30.6	27.6	1.047	3.564
at teat end	7.1	8.8	4.9	1.426	20.089	9.7	15.6	5.1	3.397	34.730
Milking time of twelve tested cows (min)						8.7	12.1	5.2	2.114	24.453

$\bar{x}$ = arithmetic mean max – maximal value in the set; *s* = decisive aberration min – minimal value in the set; *v* = coefficient of variation

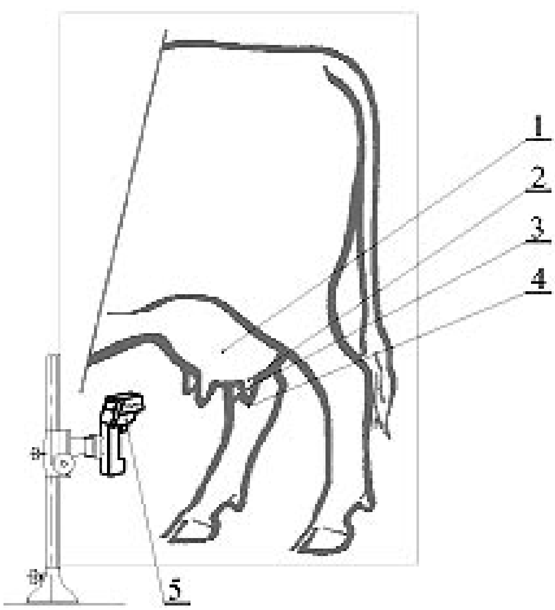

Figure 3. Places of mammary gland temperature measurements before and after milking with non-contact thermometer

1 – udder, 2 – teats at the base, 3 – middle part of teat, 4 – teat end, 5 – non-contact thermometer

Table 3. Testing of contrasts of temperature measurement place

Contrast	Difference	Limit value
Udder – teat base	0.333	1.319
Udder – teat middle	1.312	1.319
Udder – teat end	21.854	1.319*
Teat base – teat middle	0.979	1.319
Teat base – teat end	21.520	1.319*
Teats middle – teat end	20.541	1.319*

*recorded statistically significant differences

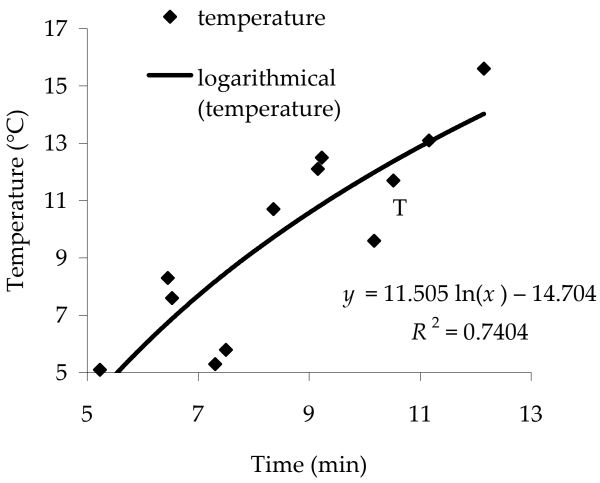

Figure 4. Dependence of teat end temperature on milking time

The temperature before milking was calculated as 23.845833 and after milking as 24.995833, the difference being 1.15000, with a limit value of 0.65036. With regard to the homogeneity aspect, the groups (before and after milking) are different.

Similarly, using the Scheffe test, the places of measurement were also tested on the significance level of 0.95 (Table 3).

The dependence of the teat end temperature on milking time was evaluated in Excel (Figure 4). Among the equations of curves to which the measured values were translated, the closest seemed to be the logarithmic function in the equation form $y = 11.505 \ln(x) - 14.704$, where the determination coefficient was 0.7404. The statistical evaluation shows that the milking time has a significant effect on the cow teat end temperature.

DISCUSSION

The examined milking house is situated in the area with continental climate, characterised by significant fluctuations of summer and winter temperatures, with limit values reaching –25°C and +35°C.

At present, dairy cow breeders in Slovakia use also non-insulated buildings, mostly due to lower financial costs. The paper confirms these claims. The external microclimate essentially decides on the climatic conditions in a stable. Janáč (1964) claimed that the internal surfaces of circumferential constructions should not be dewed as a result of water steam condensation. The difference between the air temperature and that of interior wall surfaces should not exceed 3°C, and only 1.54–2°C in the case of high air humidity. Our results confirmed the above statement when the determined difference of 3.44°C between the average air temperature in the milking house and average temperature of the milking house wall resulted in the bedewing of circumferential construction.

It is very difficult to determine immediate responses of cows to the environmental conditions. One of the possibilities how to monitor changes in mammary gland temperatures is to use thermovision. Thermovision AGA 782 uses an inbuilt display system to create a "temperature" picture of the object. The developed picture – a thermogram distinguishes isothermal areas by means of colours. The paper of Kejík and Mašková (1989) investigated the influence of teat liners made of various materials on the udder and teats as well as the influence of washing, drying and first milk on the temperature of mammary gland and its monitoring by means of thermovision. The non-contact thermometer measurements of mammary gland temperatures before and after washing gave similar results to those reported by the authors of thermograms Kejík and Mašková (1989); the mammary gland temperature status was changed only minimally: 0.4–0.6°C. The authors of thermograms further claimed that the field of udder and teat temperatures before milking was different for individual cows; the udder temperature before milking reached approximately the value of 33°C, the teat temperature was lower, reaching approximately 27.5°C in the summer season. During milking the udder temperature gradually rose, at the place where the teat liner head was attached it reached 29.8°C in the summer season, the temperature at teat ends increased as a result of underpressure straining.

At the teat end the value 7.1° was measured before the milking, which was on average by 20°C less than the value measured in the middle part of the teats. After milking the measured temperature at the tops was on average only by 2.6°C lower than before milking, which was in contradiction with the values measured by thermovision, state the authors dealing with this agenda.

Low external temperatures (daily average: minus 8.6°C) significantly influenced temperatures in the stable, waiting area before milking and in the milking house (daily average: 4.7°C), which caused considerable undercooling of the teats. These circumstances and also others such as cold liner shells set on the unsufficiently dried and undercooled mammary gland in draught conditions affect the dairy cow as widely traumatic.

The result of these aspects is considerably different temperatures of the individual parts of the cow's mammary gland.

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ABSTRAKT

Kontaktná a bezkontaktná teplometria v procese získavania mlieka

V zimnom období s priemernou vonkajšou celodennou teplotou –8,6°C boli 24 hodín sledované teploty severnej steny, stropu a podlahy v dojárni BOU MATIC 2 × 12 EXPRESWAY, ako i v čakacom priestore pred dojárňou. Bezkontaktným teplomerom RAYNGER ST 3 s laserom bol ďalej zisťovaný vplyv nízkych vonkajších teplôt na teploty mliečnych žliaz dojníc. Z analýzy vyplynulo, že nízke vonkajšie teploty a nedostatočne zateplené obvodové steny (priemerná 24-hodinová teplota bola: (t_{st} = +1,32°C), stropu (t_s = +2,65°C), podlahy (t_p = +3,29°C), ako i čakacieho priestoru pred dojárňou (t_d = +1,9°C) spôsobili i napriek vyhrievacím telesám v dojárni nevyhovujúce tepelné podmienky, spojené s podchladením mliečnej žľazy a traumatizáciou dojníc. Viacfaktorovou analýzou rozptylu boli vyhodnotené teploty mliečnych žliaz testovaných dojníc. Na hladine významnosti 0,05 je čas i miesto merania štatisticky významné.

Hodnota F-testu pre faktor času bola 12,342 s pravdepodobnosťou 0,0007. Pre miesto merania teplôt bola hodnota F-testu 1 061,979 s pravdepodobnosťou 0,0000. Z rovníc kriviek závislostí teploty na hrote ceckov od času dojenia sa najtesnejšie javila funkcia logaritmická s indexom determinácie R^2 = 0,7404.

Kľúčové slová: teploty; bezkontaktný teplomer; mliečna žľaza; dojáreň

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