Non-contact thermometry in the milking stopping control system

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ABSTRACT: The paper deals with the detection of "idle milking" times for individual quarters of the udder in a group of dairy cows (randomly selected) in a parallel 2 × 12 milking parlour. A non-contact laser thermometer Raynger ST-6 was used to measure temperatures of the inner surfaces of liners instantly after milking. In a group of 12 dairy cows, the minimum liner temperature after milking was 15.3°C, the maximum temperature was 28.9°C. It follows from the regression correlation that an increase in the cooling time by 1 second decreases the temperature of the liner inner surface by 0.0324°C. On average, fore left quarters were milked idle 2.55 min, fore right 2.21 min, rear left 0.24 min, rear right 0.56 min. Differences in the temperatures of liner inner surfaces determined between fore and rear udder quarters were statistically significant; the negative statistically significant correlation coefficient was recorded between the total milking time and the temperature of liners in fore quarters ($r = -0.7802^{++}$, resp. $r = -0.6058^{+}$).

Keywords: laser thermometer; liners; climatic and operational factors

The question of a reliable detection of the time to stop the milking and a consequent technical solution of the problem is not a recent one. The problem was seriously investigated by researchers already in the past, especially in the 1950's (Hill, 1952; Schultheis, 1955; Eades, 1956). Rossing (1972) claimed that the increasing concentration of dairy cows was connected with a wish to make the milking process automated in the last years. The automation must not only aim at the improvement of milker's work but also by taking up the controlling activity it must result in his/her mental relief. At the same time, automation must positively influence the quality of work, and above of all, exclude the "idle milking" which still occurs.

The productivity of milker's labour may be increased when he/she does no longer have to come to each animal to find out whether it has already been milked or not, and then to remove the milking unit or not. Some authors point out that to do this milkers consume 9 to 18% of the total milking time (Gerish and Bickert, 1972).

With regard to the fact that the milking out of individual udder quarters is only scarcely completed at the same time, simultaneous removal of all teat cups may cause an overmilking (idle milking) of some udder quarters (Thiel *et al.*, 1964).

The problem of idle milking has been discussed by many researchers. Tančin *et al.* (2001) stated that as a result of idle milking, or at a minimum milk flow, the counts of somatic cells in milk may increase, causing a higher occurrence of the liners oedema, various levels of aversion as well as wounds of teat ends. The milking technique plays an important role in the pathogenesis of mastitis. In this respect, idle milking is the most familiar case and the strongest traumatising factor of the mammary gland (Vegricht, 1981). It has been proved that idle milking causes serious patho-histological changes in the mucosa and udder canal. It further leads to significant changes in the chemical composition of milk, characteristic of subclinical inflammatory processes with an increase in the counts of milk somatic cells (Witzel and McDonald, 1964).

An incorrect milking technique, especially idle milking, may result in the penetration of microbes into the mammary gland not only mechanically – by pulsation, but also by the equalisation of the internal vacuum in the mammary gland – by the air aspiration (McDonald and Witzel, 1989; Fryč *et al*., 2001).

Hillerton *et al*. (1998) analysed the influence of the weight of milking unit on the cows' being milked out. Slightly better milking out was observed when the heavier unit was used, however, a greater probability of "idle" milking was recorded as well. Osteras *et al*. (l995) reported that the idle milking lasting for more than one minute increased the risk of cows' predisposition to udder diseases.

A real milk flow in the milking machine depends on the setting of delay time, that is the time from the registration of the critical value of milk flow to the milking machine's command to draw, Akam (1999).

Most indicators showing the completion of milking are set to the critical value of 0.2 l/min. There are opinions that the value is appropriate. Its possible decrease could cause the idle milking of the quarters where milking was finished sooner (Hamann, 1999). The conduction of heat in the bodies was discussed, among others, also by Kolomazník and Sedlár (1993). They characterised the conditions of heat conduction as follows:

a) *geometrical* – characterizing the shape and dimensions of the body in which the process is under way
b) *physical* – characterising physical properties of the body
c) *time* – characterising the distribution of temperatures in the body at the beginning of analysis
d) *marginal* – characterising the interaction of the body with the environment

MATERIAL AND METHODS

The aim of the study was to observe and assess a group of 12 randomly selected dairy cows in a 2 × 12 milking parlour in order to determine the times of "idle milking" for individual mammary quarters.

– Testing was carried out in the summer period in a parallel milking parlour with 2 × 12 milking stands.

– A group of 12 dairy cows was chosen randomly from the herd of 480 dairy cows.

– Temperatures of the analysed inner surfaces of liners, from which the times of "idle milking" were determined, were registered with non-contact laser Raynger ST-6 thermometer and the following basic parameters were investigated:

– temperature range: 32°C – 500°C
– accuracy: ±1% of the value
– echo time: 500 ms (95% echo)
– sensitivity : nominal 7–18 μm
– emissivity: 0.3–1.0 digitally set
– temperature display: 4-digit LCD display

It is possible to recall the last measured temperature with this thermometer.

The testing was done in such a way that immediately after the end of milking and automatic removal of the milking unit the temperatures of the inner surfaces of liners were measured through the openings at the liner heads – at the same places (2 cm below the head) – with non-contact thermometer Raynger ST-6.

In addition to the non-contact laser thermometer Raynger ST-6, the following devices may be used to register liner temperatures:

a) *thermovision camera* – e.g. Thermovision 570 (manufactured by AGEMA, Sweden). The accuracy of measurements given by the manufacturer is ±2°C
b) *contact electronic thermometer* – e.g. TESTO 615 (manufactured by Lenzkirch, Germany) with the accuracy of measurements ±0.4°C

Raynger ST-6 with laser is more accurate if compared with thermovision camera. The contact thermometer is more accurate than Raynger ST-6, but as a result of time losses that could occur during its installation into liner nozzles after the end of milking, measurement results would be distorted considerably.

The liner cooling progress was verified in a set of 12 liners from which an average value was calculated.

We have the temperature of environment t_o and the law of heat exchange between the surface of the body and the ambient environment. Marginal conditions of the third kind characterise the law of heat exchange between the surface and the ambient environment in the process of cooling or heating of the body. This phenomenon is described by Newton's law. In line with Newton's law, the volume of heat penetrating a unit of the body area during a unit of time is proportionate to the difference between the temperature of the body surface (t_s) and the environment (t_o), (t_s–t_o):

$$q = \alpha\ (t_s - t_0) \qquad \text{(J)}$$

where: α = the coefficient of temperature penetration

Climatic and operational temperatures influencing the liner temperatures were analysed.

RESULTS AND DISCUSSION

During their dynamic and static stress, i.e. during their pulsating without the flow of milk, liners are influenced by a considerable number of factors and interaction relations having a various impact on the resulting temperature. Furthermore, the number of factors increases during milking as shown by the analysis of climatic and operational factors given in Figure 1. Climatic and operational factors were divided into substantial (position 1–12), measurable under laboratory and operational conditions, and complementary (position 13–18), assessed as difficult or even impossible to measure.

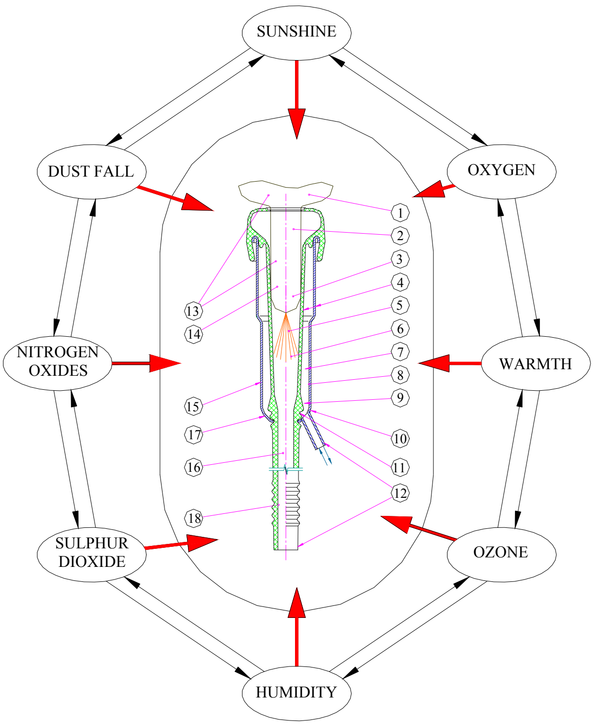

Figure 1. Climatic and operational factors influencing final temperatures of liners

Significant: 1 – udder temperature, 2 – teat temperature, 3 – teat size, 4 – milking parlour temperature, 5 – milk temperature, 6 – milk flow time, 7 – liner pulsation, 8 – temperature of the air let into inter-wall chambers during pulsation, 9 – quality of liners, 10 – teat cup material, 11 – liner tension level, 12 – shapes and size of liners and teat cups

Complementary: 13 – pre-milking udder hygiene, 14 – milking of the first milk strippings, 15 – short-time heating of liners when fitting in, 16 – speed of under-teat chambers milk outflow, 17 – removal of milking unit from the udder, 18 – metabolic activity of microorganisms

In the evaluation of temperatures of the inner surfaces of liners we formulated the following basic presupposition: at a milking parlour temperature of +4°C and 86% relative humidity the cooling of removed liners was linear – in 29 seconds the liners cooled down on average 1°C.

The regression line is expressed by the equation $y = -0.0324x + 28.973$ and given in Figure 2. The regression relation shows that if the cooling time is increased by 1 second, the liner wall temperature decreases by 0.0324°C.

Hejlíček *et al.* (1987) stated that the average milking time for individual dairy cows was a significant indicator of milking quality. Adequately fast milking with the complete emptying of the udder is evaluated as good, while a long milking time is always unfavourable. The lengthening of milking time is usually connected with idle milking when teat cups remain fixed to the udder even after the milk flow is over. The above-mentioned facts were also confirmed by our results (Table 1). Out of the 12 observed dairy cows, the fastest milking time of 6.15 minutes was observed for dairy cow no. 11; at the same time, the dairy cow showed the shortest idle milking time, amounting to 1.50 and 1.10 min in the fore quarters while in the rear quarters it was 0.18 and 0 min. The most unfavourable result was observed for dairy cow no. 2 with 11.15 min of the total milking time. The idle milking time for the fore quarters reached 6.42 and 4.02 min while for the rear quarters it was 0 and 2.18 min. In general, a relatively long milking time was registered – 8.51 min on average, fore quarters reaching, on average, 2.55 and 2.21 min of idle milking, the rear quarters 0.24 and 0.56 min.

The significance of differences in the liner temperature after the end of milking according to in-

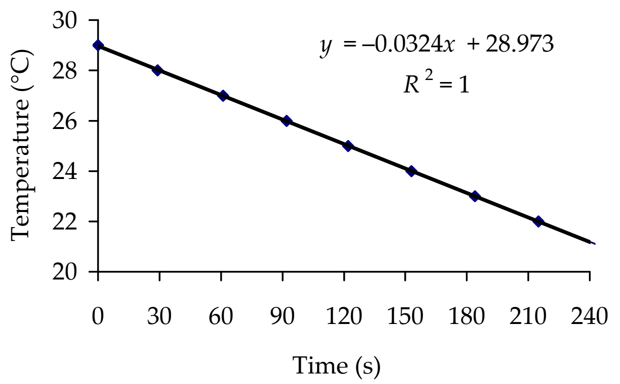

Figure 2. The cooling progress of removed liners after the end of milking

Table 1. Statistically processed measured values of liner inner temperatures

Statistical data	Liner temperatures in the milking unit immediately after the end of milking (°C)				Total milking time (min)	Idle milking time (min)			
	fore quarters		rear quarters			fore quarters		rear quarters	
	1 – left	2 – right	3 – left	4 – right		1 – left	2 – right	3 – left	4 – right
$\bar{x}$	23.30	24.12	27.79	27.29	8.51	2.55	2.21	0.24	0.56
min.	15.3	21.3	25.0	24.0	6.15	1.50	1.10	0	0
max.	25.6	26.1	28.9	28.4	11.15	6.42	4.02	1.50	2.18
s	2.7309	1.5661	1.1180	1.3674	1.2890	1.3069	0.9507	0.4212	0.8440
v	11.720	6.492	4.023	5.010	15.147	51.221	43.037	177.371	149.175

Table 2. Significance of differences in the temperatures of liners according to udder quarters

Liner temperature (°C)	Fore quarter		Rear quarter	
	1 – left	2 – right	3 – left	4 – right
Fore quarters 1 – left	0	–	+	+
Fore quarters 2 – right	–	0	+	+
Rear quarters 3 – left	+	+	0	–
Rear quarters 4 – right	+	+	–	0

$^{+}P < 0.05$

dividual udder quarters is given in Table 2. The data show that the detected differences in liner temperatures between fore and rear quarters of the udder were statistically significant. A statistically significant negative correlation coefficient ($r = -0.7802^{++}$, or $r = -0.6058^{+}$) was recorded between the total milking time and the liner temperature in fore quarters.

The relations are graphically represented by parabolic curves given in Figures 3 and 4. The index of determination (R^2) of the shape of parabola equation $y = -0.6136x^2 + 8.8858x - 6.9461$ of the relation of temperature on fore quarters (1 – left) to the total milking time reached 0.8761, of the relation of temperature on fore quarters (2 – right) to the total milking time at the equation shape $y = -0.1355x^2 + 1.5905x + 20.606$ it reached 0.4066.

It was determined that the idle milking lasting more than 1 min increases the risk of cow predisposition to an udder disease (Osteras and Lund,

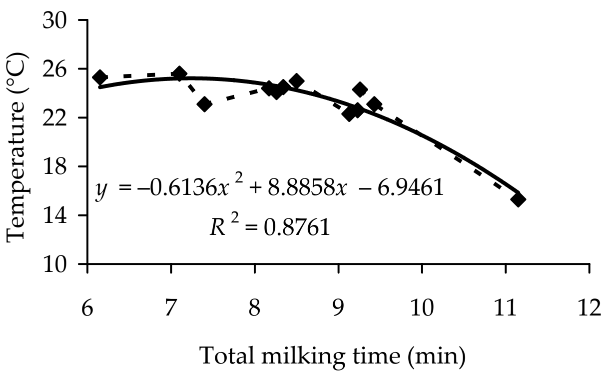

Figure 3. Regression relation between total milking time and liner temperatures on fore quarters (1 – left)

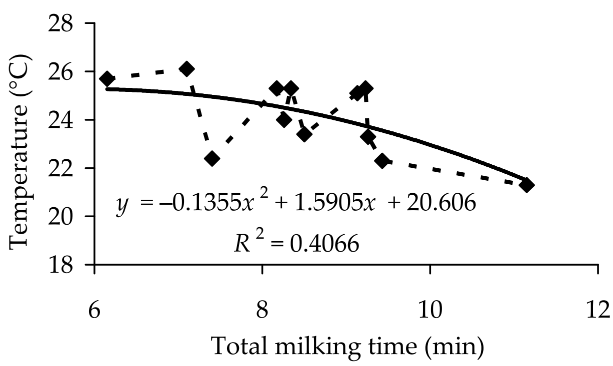

Figure 4. Regressive relation between total milking time and liner temperatures on fore quarters (2 – right)

1988). Measurements showed that all 12 dairy cows were "idle milked" on fore quarters (left and right), i.e. 100%, for more than 1 min. A more than 1 min idle milking on the rear left quarter was observed in one case, making up 8.33%, on the rear right quarter in three cases, i.e. 25.0%.

The stopping of milking is a significant process influencing the good health of the udder. In the past, the manufacturers of milking machines decided to tolerate some overmilking (idle milking) rather than to design complicated devices for a gradual, not sudden, removal of teat cups from individual quarters. Unfortunately, this situation has remained until now. A significant part of the milking units works in such a way that all teat cups are removed simultaneously, when the total milk flow drops below 0.2 l/min. This paper also confirms that the idle milking problem is to be solved and it must be addressed quickly and efficiently.

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Received: 04–10–15
Accepted after corrections: 05–02–01

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