MONITORING OF THE MACHINE MILKING PROCESS WITH APPLICATION OF INFRARED THERMOGRAPHY

PETR JUNGA[1], PETR TRAVNICEK[1], JURAJ RUZBARSKY[2]

[1]Mendel University in Brno, Faculty of AgriSciences, Department of Agriculture, Food and Environmental Engineering, Brno, Czech Republic

[2] Technical University of Kosice with a seat in Presov, Faculty of Manufacturing Technologies, Slovak Republic

DOI: 10.17973/MMSJ.2016_09_201652

e-mail: p.junga@mendelu.cz

The paper is focused on monitoring of the machine milking process by infrared thermography method. The goal of the paper is thermography monitoring of the influence of machine milking on the udder and teats surface temperature and statistics valuation of measured values. Our study claimed suitability of IRT method for monitoring of machine milking. Statistical evaluation claimed statistically significant difference between temperatures of teats before and after machine milking. Probably it is due to direct contact of milking machine with teats causing mechanical stress of tissues. This is significant risk factor for infections and related financial losses. It is necessary to operate technological equipment for milking with suitable characteristics.

KEYWORDS

monitoring, infrared thermography, machine milking, surface temperature

1 INTRODUCTION

The milk aquisition process is important part of milk industry. The milking of dairy in milking houses is affected especially by different conditions as system of stabling, milking house type, milking machine technology, staff expertness, psychic and ethological singularities of annimals. The surface temperature of animal is quick indicator of mechanical traumatising of skin and texture or inflammatory procedures in organism. Infrared thermograhy is modern perspective method for monitoring of surface tepmerature. Monitoring of technological equipment for machine milking and its influence on animals is very important factor for prevention of infections and economical losses.

Mechanical milking can cause circulatory changes (con-gestionand/oroedema) in teat tissue fluids, producing an increase in teat wall thickness and teat skin temperature [Hamann et al. 1994]. Milking performed with unsuitable characteristics, such as excessive vacuum levels [Hamann et al., 1993], faulty or absent pulsation [Capuco et al. 1994], inappropriate pulsation rate [Hamann, 1996] or overmilking [Hillerton et al. 2002], can lead to persistence or high magnitudes of these circulatory changes, which in turn can affect local defence mechanisms, increasing the risk of infections. [Hovinen et al. 2008] stated that increasing herd size and the rapid increase in labor costs in Europe have required greater automation in livestock production. Author reported that mastitis is the most common disease in dairy cows and causes the heaviest economic losses to the dairy industry. Recent research shows that milking process was improved especially, by the influence of construction elements, which was verified under laboratory and operational conditions [Karas 2004]. Author also stated that technological equipment of milking houses is closely related to their construction part. Several studies have applied IR thermography to determine radiant and convective heat losses [Phillips 1994 et al.; Ek et al. 1999]. IR thermography of the body surface is a simpler procedure than the more conventional approaches for measuring heat production and methane production, because it is non-invasive, relatively inexpensive and easily obtained [Montanholi et al. 2008]. Infrared thermography (IRT) is a noninvasive method for measuring radiated heat emitted by the skin, reflecting subcutaneous circulation and metabolism [Jones 2002]. [Kotrba et al. 2008] used infrared thermography to determine the coat surface temperature of seven captive eland females in different ambient temperature conditions and compared them with that seen in cattle. [Vitazek 2008] reported other application of IRT in food industry and importance of the surface temperature for assessing the effect of the dryer condition on the energy requirements and the economics of its operation.

The goal of the paper is thermography monitoring of the influence of machine milking on the udder and teats surface temperature. Further part of the paper is focused on statistics valuation of measured values.

2 MATERIAL AND METHODS

The IRT experimental measuring was carried out under operational conditions in a milking house with 2 × 2 Westfalia tandem milking machine, during the summer season (August 2015). In the time of the experimental measuring there were 34 dairy cows on the farm. Average annual production was 6 300 liters of milk per cow. The following characteristics were monitored contemporary with IRT imaging in the milking house during the milking process:

- air temperature in the milking house (°C),
- air flow velocity in the milking house ($m \cdot s^{-1}$),
- air humidity in the milking house (%),
- distance of measured object (m),
- temperature of udders before and after milking (°C),
- temperature of teats before and after milking (°C).

The thermal analysis of the udder and teats temperature assessment before and after milking was carried out in the whole group, i.e. 19 cows.

Thermal analyses were performed by FLUKE thermal camera. For thermal imaging measurement purposes was measured the air temperature, air humidity, distance from the monitored object and emissivity. Determination of emissivity was executed by creation of measuring points on the objects, where was executed thermal analyses. At these points was measured temperature with using OMEGA HH11 contact thermometer (accuracy of temperature measurement: ± 0.1 °C).

The air temperature and relative humidity were measured using KIMO AMI 300 multifunction equipment. The air velocity and temperature were measured with using a telescopic vane probe type HET 14 (in the range of 0.8 to 25.0 m/s and -20 to 80 °C) featuring the temperature measurement accuracy of ±1 °C. The relative humidity were measured with using a telescopic hygrometry probe SVTH (in the range of 5.0 to 95.0% relative humidity) featuring the measurement accuracy of ±4%. The temperature and humidity were measured in the close vicinity of the thermal camera and measuring objects. The reflected temperature was not measured because any heat sources were not in the surroundings, which could influence the measurement. The reflected temperature is caused by close heat source which can influence temperature of measured objects. Conditions of thermography measurement: cloudy conditions, air temperature 19 °C, air velocity 0.50 $m \cdot s^{-1}$, relative humidity 55 %.

The distance of the camera from measuring objects was determined using Leica DISTOtm A5 laser EDM device (measurement accuracy: ± 1.5 mm at a distance between 0.2 and 200 m). The thermal imaging measurement as such was conducted using Fluke Ti32 thermal camera (FOV: 45°) and Fluke SmartView 3.2 software.

3 RESULTS AND DISCUSSION

This part presents main results of our experimental survey and statistical evaluation of measured values. All cows were measured before and after machine milking process.

We can see examples of thermogram at Fig. 1 and Fig. 2. Next text is word interpretation of thermograms. Fig. 1 shows thermogram of udder and teats before machine milking. We can see temperature of front udder 35.6 °C and temperature of hind udder 35.0 °C. Temperature of front teat is 30.9 °C and temperature of hind teat is 30.8 °C. It is evident that temperature of front udder is about 0.57 °C higher in comparison with mean value. Temperature of hind udder is about 0.03 °C lower in comparison with mean value. Temperature of front teat is about 0.88 °C lower in comparison with mean value. Temperature of hind teat is about 1.17 °C lower in comparison with mean value.

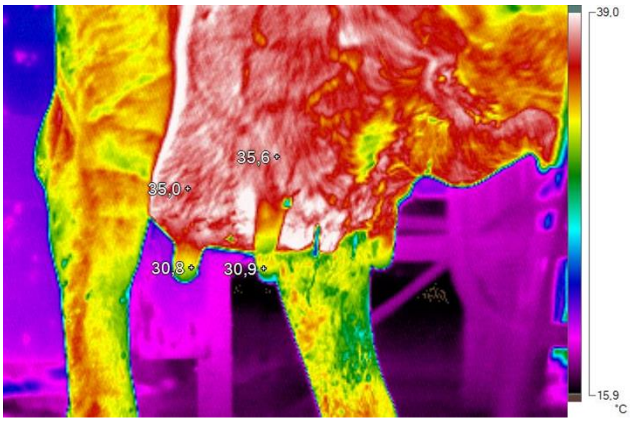

Figure 1. Example of thermogram before milking – cow No.252

Fig. 2 shows thermogram of udder and teats after machine milking. We can see temperature of front udder 36.0 °C and temperature of hind udder 36.5 °C.

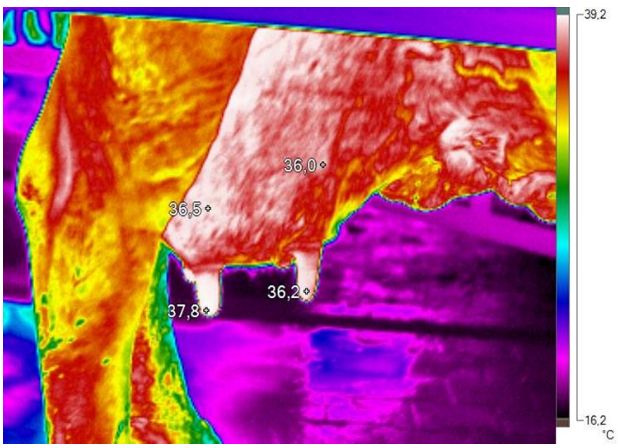

Figure 2. Example of thermogram after milking – cow No.252

Temperature of front teat is 36.2 °C and temperature of hind teat is 37.8 °C. It is evident that temperature of front udder is about 1.76 °C higher in comparison with mean value.

Temperature of hind udder is about 1.52 °C higher in comparison with mean value. Temperature of front teat is about 0.65 °C higher in comparison with mean value. Temperature of hind teat is about 1.92 °C lower in comparison with mean value.

Main part of performed descriptive statistical evaluation there are mean, median, standard deviation, Shapiro-Wilk test of normality, kurtosis and skewness. Table 1 present values of descriptive statistics. There was performed analysis of variance (ANOVA) method for comparison of mean values.

		Mean	**Median**	Standard deviation	p Shapiro-Wilk test	**Kurtosis**	**Skewness**
Before milking	Hind teat	31.968421	31.9	1.539860	0.78671	-0.154272	-0.85913
	Hind udder	35.031579	35.0	0.946956	0.4719	0.217188	0.44082
	Front teat	31.784211	31.8	1.453831	0.75191	-0.073608	-0.93668
	Front udder	34.657895	35.0	1.293280	0.11472	-0.878071	0.00407
After milking	Hind teat	35.884211	36.0	1.088456	0.6713	-0.705825	1.15862
	Hind udder	34.978947	35.2	1.190042	0.03647	0.133228	-1.54730
	Front teat	35.552632	35.7	1.042629	0.31127	-0.859777	0.59556
	Front udder	34.236842	34.0	1.604580	0.6814	0.030417	-0.33829

Table 1. Results of descriptive statistics

As we can see in Table 1 the hypothesis of data normality meet all of data files with the exception of dates related to udders. We used Kruskal-Wallis test for evaluation of data files related to udders.

Evaluation of variance homogeneity is important condition for using of ANOVA, so we used Leven and Brown-Forsyth tests (results are presented in Table 2).

Test	**p**	**Homogeneity**
Leven	0.067193	Yes
Brown-Forsyth	0.063011	Yes

Table 2. Results of variance homogeneity

Subsequently there was used Tukey´s test for multiple comparisons. According to hypothesis there were founded statistically significant differences in temperatures of teats before and after machine milking (presented in Table 3). Probably it is due to direct contact of milking machine with teats causing mechanical stress of tissues.

	Hind teat before milking	Front teat before milking	Hind teat after milking	Front teat after milking
Hind teat before milking	***	0.971955	0.000150	0.000150
Front teat before milking	0.971955	***	0.000150	0.000150
Hind teat after milking	0.000150	0.000150	***	0.860487
Front teat after milking	0.000150	0.000150	0.860487	***

Table 3. Results of Tukey´s range test

There are presented results of Kruskal-Wallis test for evaluation of data files related to udder in the Table 4. There were not founded statistically significant differences in temperatures of udder before and after machine milking (Table 4). Probably it is due to indirect contact of milking machine with udder without existence of mechanical stress.

	Hind udder before milking	Front udder before milking	Hind udder after milking	Front udder after milking
Hind udder before milking	***	1.000000	1.000000	0.665527
Front udder before milking	1.000000	***	1.000000	1.000000
Hind udder after milking	1.000000	1.000000	***	0.695664
Front udder after milking	0.665527	1.000000	0.695664	***

Table 4. Results of Kruskal-Wallis test

Temperatures of udder before machine milking are in the range 35.0 °C to 36.9 °C. Temperatures of udder after machine milking are in the range 33.0 °C to 36.8 °C. Temperatures of teats before machine milking are in the range 29.1 °C to 34.7 °C. Temperatures of teats after machine milking are in the range 35.8 °C to 37.2 °C. Mean temperature of front udder before milking is 34.66 °C and mean of hind udder is 35.03 °C. Mean temperature of front teat before milking is 31.78 °C and mean of hind teat is 31.97 °C. Mean temperature of front udder after milking is 35.24 °C and mean of hind udder is 34.98 °C. Mean temperature of front teat after milking is 35.55 °C and mean of hind teat is 35.88 °C. There is statistically significant difference between temperatures of teats before and after machine milking. Temperature of teats after milking is higher as well as with [Karas 2004] where mean temperature increased from 29.5 °C to 30.3 °C. There is not statistically significant difference between temperatures of udder before and after milking.

4 CONCLUSION

Results of our study confirmed that milk acquisition process with using of machine milking can influenced surface temperature of teats. This is significant risk factor for infections and related financial losses. It is necessary to operate technological equipment for milking with suitable characteristics (mainly suitable under pressure). Our study claimed suitability of infrared thermography method application as fast indicator of influence machine milking on surface temperature of teats.

REFERENCES

[Alejandro 2014] Alejandro, M., Romero, G., Sabater, J. M., Diaz, J. R. Infrared thermography as a tool to determine teat tissue changes caused by machine milking in Murciano-Granadina goats. Livestock Science, 2014, Vol.160. pp. 178–185. ISSN 1871-1413

[Capuco et al. 1994] Capuco, A., Mein, G., Nickerson, S., Jack, L., Wood, D., Bright, A., Aschenbrenner, R., Miller, R., Bitman, J. Influence of pulsation-less milking on teat canal keratin and mastitis. Journal of Dairy Science, 1994. Vol.77. pp. 64–74. ISSN 0022-0302

[Ek 1999] Ek, J. R., Bell, E. F., Nelson, R. A., Radhi, M. A. Infrared thermographic calorimetry applied to preterm infants under radiant warmers. Journal of Thermal Biology, 1999, No.24. pp. 97–103. ISSN 0306-4565

[Hamann 1993] Hamann, J., Mein, G., Wetzel, G. Teat tissue reactions to milking: effects of vakuum level. Journal of Dairy Science, 1993. Vol.76. pp. 1040–1046. ISSN 0022-0302

[Hamann 1994] Hamann, J., Burvenich, C., Mayntz, M., Osteras, O., Haider, W. Machine-induced changes in the status of the bovine teat with respect to the new infection risk. Teat Tissue Reactions to Machine Milking and new Infection Risk. Bulletin of the International Dairy Federation, 1994. Vol.297. pp. 13–22. ISSN 0250-5118

[Hamann 1996] Hamann, J., Mein, G. Teat thickness changes may provide biological test for effective pulsation. Journal of Dairy Research, 1996. Vol.63. pp. 179–189. ISSN 0022-0299

[Hillerton 2002] Hillerton, E., Pankey, J., Pankey, P. Effect of over-milking on teat condition. Journal of Dairy Research, 2002. Vol.69. pp. 81–84. ISSN 0022-0299

[Hovinen 2008] Hovinen, M., Siivonen, J., Taponen, S., Hänninen, L., Pastell, M., Aisla, A.M, Pyörälä, S. Detection of Clinical Mastitis with the Help of a Thermal Camera. Journal of Dairy Science, 2008, Vol.91, No.12. pp. 4592-4598. ISSN 0022-0302

[Jones 2002] Jones, B. F., Plassmann, P. Digital infrared thermal imaging of human skin. IEEE Engineering in Medicine and Biology Magazine, 2002, Vol.21. pp. 41–48. ISSN 2154-2287

[Karas 2004] Karas, I., Galik, R. Contact and non-contact thermometry in the milk acquisition process. Czech Journal of Animal Science, 2004, Vol.49, No.1. pp. 1-7. ISSN 1212-1819

[Kotrba 2007] Kotrba, R., Knizkova, I., Kunc, P., Bartos, L. Comparison between the coat temperature of the eland and dairy cattle by infrared thermography. Journal of Thermal Biology, 2007, Vol.32, No.6. pp. 355-359. ISSN: 0306-4565.

[Montanholi 2008] Montanholi, Y.R., Odongo, N.E., Swanson, K.C., Schenkel, F.S., McBride, B.W., Miller, S.P. Application of infrared thermography as an indicator of heat and methane production and its use in the study of skin temperature in response to physiological events in dairy cattle (Bos taurus), Journal of Thermal Biology, December 2008, Vol.33, No.8. pp. 468-475, ISSN 0306-4565

[Phillips 1994] Phillips, P. K., Sanborn, A. F. An infrared, thermographic study of the surface temperature in three ratites: ostrich, emu and double-wattled cassowary. Journal of Thermal Biology, 1994, No.19. pp. 423–430. ISSN 0306-4565

[Vitazek 2008] Vitazek, I., Tirol, J. Relation between surface temperature and dryer operation. Research in Agricultural Engineering, 2008, Vol.54. No.4. pp. 176-182. ISSN: 1212-9151

CONTACTS:

Ing. Petr Junga, Ph.D.
Ing. Petr Travnicek, Ph.D.
Mendel University in Brno
Faculty of AgriSciences
Department of Agriculture, Food and Environmental Engineering
Zemedelska 1,613 00 Brno, Czech Republic
Tel.: +420 545 132 368, +420 545 132 374
e-mail: petr.junga@mendelu.cz, petr.travnicek@mendelu.cz

Assoc. prof. Ing. Juraj Ruzbarsky, Ph.D.
Technical University of Kosice with a seat in Presov
Faculty of Manufacturing Technologies
Department of Manufacturing Processes Operation
Bayerova 1, 080 01 Presov, Slovak Republic