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THE INFLUENCE OF SELECTED FACTORS ON SHAPING OF MILK TEMPERATURE DURING COW MACHINE MILKING

Summary

In the research the assessment of the impact of sensors found in the milking unit during the process of machine cow milking on selected metrological properties of temperature sensors installed in a milking cluster has been done. The analyses have been made on the basis of the temperature curves of milk flow in cows' udder quarters obtained during the cowshed tests. In the research a microprocessor measuring system has been used. The system has been designed in the Institute of Biosystem Engineering at the University of Life Sciences in Poznan. The system is cooperating with thermistors installed in teat cups. The results of variance analysis has shown statistically highly essential influence of the thermistor's initial temperature and sort of a quarter on the time of establishing the maximum milk temperature.
***Keywords**: temperature sensors, diagnostics, machine milking, milk temperature*

WPŁYW WYBRANYCH CZYNNIKÓW NA KSZTAŁOWANIE SIĘ TEMPERATURY MLEKA W CZASIE DOJU MASZYNOWEGO KRÓW

Streszczenie

W pracy dokonano oceny wpływu czynników występujących na stanowisku udojowym w czasie doju maszynowego krów na wybrane własności metrologiczne czujników temperatury zamontowanych w aparacie udojowym. Analiz dokonano w oparciu o uzyskane w trakcie testów oborowych termogramy spływu mleka z ćwiartek wymion krów. Do badań wykorzystano opracowany w Instytucie Inżynierii Biosystemów Uniwersytetu Przyrodniczego w Poznaniu mikroprocesorowy system pomiarowy współpracujący z termistorami zamontowanymi w kubkach udojowych. Wyniki analizy wariancji wykazały statystycznie wysoko istotny wpływ temperatury początkowej termistora oraz rodzaju ćwiartki na czas ustalenia wartości maksymalnej temperatury mleka.
***Słowa kluczowe**: czujniki temperatury, diagnostyka, dój maszynowy, temperatura mleka*

1. Introduction

On the milking systems market there is a limited number of constructional solutions equipped in temperature sensors available. Milk temperature measurements are realised both in milking clusters that possess diagnostic functions and in automatic milking systems [7].

The research which has been carried out in Poland and other countries has confirmed the usefulness of milk temperature measurement. The measurement taking place during machine milking aims at detecting selected physiological conditions in cows (heat, early pregnancy) as well as illnesses of quarters of cows' udders [3, 7, 9, 11, 13]. In the Institute of Biosystem Engineering in Poznan University of Life Sciences a microprocessor measuring system has been built. It cooperates with thermistor temperature sensors installed in teat cups. Thanks to the parameters automatic measurement of milk temperature is possible during machine milking with high resolution of the measurements being kept [5].

One of the most important tasks that involves the process of construction of a new measuring system is to define the factors that might have an impact on the shape of milk temperature measurements taking place in a teat cup. Each measuring sensor is characterised by static and dynamic parameters. Their neglecting may lead to misinterpretation of measurement results. At present metrology does not find it difficult to compensate static errors. However, the dynamics of thermometric sensor is straightforwardly connected with its thermal inertia and thermal resistance which appears on the way between the medium tested and the sensor [16]. The basic factors that influence the dynamics include [10]:

- the material the sensor is made of,
- the shape and size of the sensor,
- working point and the range of temperatures measured,
- the kind of medium, its viscosity, milk flow speed and other parameters,
- the way the sensor is placed,
- the state of sensor's surface,
- others.

It is crucial to know the dynamic properties of a sensor and the conditions of temperature measurement in order to define the minimal time the sensor must be located in the environment of set temperature measured [10].

The dynamic properties of temperature sensor cannot be defined on its data plate as they depend on the way the sensor is used [16]. In industrial usages, where durability of a measuring device is of greatest importance, there are some shields that protect a thermometer from mechanical and chemical influence. In these cases the report of dynamic properties gets complicated. The dynamic properties of thermometers should be defined in their natural operating conditions since reconstruction of these conditions in a laboratory in order to identify the dynamics is almost impossible [16].

In literature the problem of the impact of factors occurring in a milking unit during cow milking on metrological properties of milk temperature sensors installed in teat cups

has not been thoroughly analysed so far. However, the necessity to measure the exact maximum milk temperature aiming at heat and early stage of pregnancy detection is mentioned in literature [2, 4]. The analysis of thermograms in order to evaluate the state of health of udder quarters requires dynamic properties sensors installed in teat cups being taken into consideration [6].

2. Research aim

The aim of the research was to define how the factors occurring in a milking unit influence the shaping of milk temperature flowing out of cow udder quarters. The range of research included the analysis of the impact of the initial temperature of thermistor (installed in a teat cup), time of milking, type and health of udder quarters on the time required to set the maximum value of milk temperature during machine milking.

3. Materials and methods

The cowshed research was carried out in a private farm in Kościan district (Great Poland Voivodeship) in spring 2013. The research included a group of 18 cows currently being milked in the cowshed. During the tests the same routine procedures typical for cow milking in the farm were maintained.

The research has been carried out during eight milking processes (four in the morning and four in the evening). Each of the milkings was preceded by manual taking of a milk sample out of each quarter. Microbiological tests have been carried out in a laboratory in Krotoszyn (Great Poland Voivodeship).

To carry out the research a special milking cluster constructed in the Institute of Biosystem Engineering has been used. It consists of following components:

– Milking cluster Classic 300 made in GEA Farm Technologies equipped with four thermistor temperature sensors type TT4-5KC3-25-3500-UPP (figure 1). The metrological parameters of thermistors are shown in table 1.

Source: own research / Źródło: badania własne

Fig. 1. Thermistor type TT4-5KC3-25-3500-UPP installed in a milking cluster Classic 300 of GEA Farm Technologies company

Rys. 1. Termistor TT4-5KC3-25-3500-UPP zamontowany w aparacie udojowym Classic 300 firmy GEA Farm Technologies

– Automatic register of measuring signals of high measurement resolution, supply module and other electronic equipment.

– Stainless-steel hanger with integrated connector and electronic pulsator (all the devices are produced by Polanes company in Bydgoszcz) and other milking equipment.

Detailed technical data and functional abilities of the microprocessor system of temperature diagnostics in cows were presented in literature [5-7].

Table 1. The selected metrological parameters of thermistor type TT4-5KC3-25-3500-UPP

Tab. 1. Wybrane właściwości metrologiczne termistora TT4-5KC3-25-3500-UPP

Nominal resistance (for T=25 °C)	5000 Ω
Measuring range	-40÷150°C
Material constant	3976 K
Thermistor accuracy	±0,1°C in temperature range 30÷45°C
Maximum value of current supply	100 µA
Type of shield	Stainless steel with wall's thickness of about 0,2 mm

Source: data of Tewa Temperature Sensors Sp. z o.o. company from Lublin / Źródło: dane producenta firmy Tewa Temperature Sensors Sp. z o.o. z Lublina

The values of milk temperature registered during milkings served to make thermograms of milk flow out of cow quarters. It has been done with the use of Excel 139 spreadsheet. The number of somatic cell counts SCC has been assigned to the course of milk temperature. In the research the results of inactive teats and sour samples have not been taken into account as they could not be microbiologically tested.

Selected factors typical for the milking unit were considered as crucial for metrological properties of temperature sensors installed in teat cups [1, 3, 8, 10, 12]:

A. Thermistor initial temperature – initial parameters of thermistors still before the outflow of first milk streams have been defined on the basis of thermograms registering the milk flow out of quarters. In statistical analyses three ranges of initial temperature values have been assumed: I. below 20,00°C; II. 20,00-29,99°C and III. above 29,99°C.
B. Time of milking: morning (M), evening (E).
C. Type of udder quarter: rear left (RL), rear right (RR), front left (FL), front right (FR).
D. The state of health of udder quarters – quarters where somatic cell counts in milk reached up to 400 thousands per 1 ml were acknowledged healthy. The quarters where somatic cell counts in milk were higher (above 400 thousands per 1 ml) were acknowledged as sick.

In the work it has been assumed that the type of material the sensor was made of, the shape and size of the sensor and the way it is located in a teat cup remained unchanged during the research. Actually it was impossible to monitor its surface during the time of milk flow out of quarters. It was also assumed that the sensor runs properly in a particular range of temperature and then demanded accuracy of measurement is kept.

The output parameter analysed of the thermistor installed in a teat cup was the time of setting maximum milk temperature. The evaluation of the impact which the factors appearing in the milking unit have on the process of milk temperature shaping has been done with the use of variance analysis. F Snedecor test (α=0,05 and α=0,01) [14] and for calculations software STATISTICA 7 PL [15] have been used.

4. Research results

The research done on the group of 18 cows made it possible to make 139 milk flow thermograms from individual udder quarters. They have been a source for further analyses. First, for the cows milked the maximum value of milk temperature has been indicated. To receive unique data the highest values of milk temperature registered automatically during cow milking have been analysed.

The highest maximum value of milk temperature amounted to 38,8°C. As the model of maximum milk temperature does not exist in literature, it was assumed on the basis of values obtained in other research [4] that the correct maximum milk temperature should be at least 37,50°C. For 139 registered values, 123 results were equal or higher than the temperature of 37,50°C and 16 lower temperature values (table 2).

Among 16 maximum temperature values below 37,50°C only in two cases there were extremely low values of maximum milk temperature. They occurred in case of cow number 6426 in its front left quarter, which is shown in figure 2.

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Table 2. The cases of milkings with maximum milk temperature below 37,50°C
Tab. 2. Przypadki dojów o maksymalnej temperaturze mleka poniżej 37,50°C

Maximum milk temperature [°C]	Cow number	Type of udder quarter	SCC per 1 ml (x10^3)	Time of milking	Thermistor initial temperature [°C]
32,69	6426	FL	5694	E	26,23
34,23	6426	FL	4440	M	25,06
36,25	1145	RR	9	E	32,24
36,54	1154	FR	559	M	11,61
36,57	3058	FL	8127	M	27,42
36,62	1154	FR	575	E	11,75
37,27	6439	FR	65	M	31,00
37,28	1145	FR	11	E	30,21
37,29	9414	FR	23	E	31,43
37,34	9421	FR	10	E	26,44
37,41	1154	FL	7	M	11,44
37,43	1145	FR	12	M	29,09
37,46	6426	FR	1835	M	25,68
37,48	6422	FR	21	M	11,86
37,48	1154	FL	6	E	11,96
37,48	0809	FL	196	M	13,99

Source: own research / Źródło: badania własne

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Fig. 2. Milk flow thermogram for front left quarter of cow number 6426 with really low maximum value of milk temperature
Rys. 2. Termogram spływu mleka z ćwiartki przedniej lewej krowy o numerze oborowym 6426 o bardzo małej wartości temperatury maksymalnej mleka

Table 3. Collective setting-up of variance analysis results
Tab. 3. Zbiorcze zestawienie wyników analizy wariancji

Specification	Number of samples	Time of setting maximum milk temperature [s]		Significance level		
				Computational	Tables (α=0,05 i α=0,01)	
		$\bar{t}$	SD*	F	$F_{0,05}$	$F_{0,01}$
Thermistor initial temperature:				15,26	3,06	4,82
Below 20,00°C	33	212,64	130,77			
20,00-29,99°C	78	119,51	51,68			
Above 29,99°C	28	146,21	72,86			
Time of milking:				0,63	3,90	-
Morning	70	152,96	89,98			
Evening	69	140,96	88,59			
Type of udder quarter:				5,29	2,66	3,98
Rear left	35	133,00	48,36			
Front left	36	115,83	66,47			
Front right	36	149,86	79,80			
Rear right	32	197,78	129,91			
The state of health of udder quarters:				0,77	3,90	-
SCC up to 400 thousand per 1 ml	115	143,96	72,71			
SCC above 400 thousand per 1 ml	24	161,54	145,73			

* Standard deviation [s]

Source: own research / Źródło: badania własne

There was high amount of somatic cell counts (SCC) in this quarter. It seems, however, that the probable reason for gaining low values of maximum milk temperature were the low values of milk flow intensity. It is probable that the thermistor sensor installed in a teat cup might not have been completely swilled with milk.

In table 3 cumulative results of variance analysis have been put together.

The analysis of variance has shown that the time of milking as well as the state of health of quarters do not influence (they are statistically irrelevant) the time of setting maximum milk temperature. The average time of setting the maximum milk temperature was shorter for evening milkings and for healthy quarters (SCC below 400 thousands per 1 ml of milk). However, the type of udder quarter and the initial temperature of thermistor has occurred to be highly statistically relevant to establish the time of maximum milk temperature.

On the basis of research results it was found that for a sensor type TT4-5KC3-25-3500-UPP maximum values of milk temperature have been registered after average time of approximately 120 sec.

The obtained research results will be used to detect heat and early pregnancy in cows. However, the analysis of thermograms illustrating milk flow out of cows quarters for diagnostic purposes requires consideration of possible occurrences of disturbances which affect the conditions of temperature measurements in teat cups.

5. Conclusions

1. The time of setting the maximum milk temperature during cow machine milking depends to the highest degree on dynamic properties of thermistor sensors installed in teat cups.
2. The shortest average time of swilling the sensor type TT4-5KC3-25-3500-UPP installed in a teat cup to set maximum milk temperature amounted to approximately 120 sec.

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This work has been funded by the Polish Ministry of Science. This study presents initial work started in the framework of governmental projects "*Diagnostics of physiological states and health of cows with the usage of intelligent milk temperature sensors*" (No N N313 787040).