Bulgarian Journal of Agricultural Science, 19 (No 6) 2013, 1437-1444
Agricultural Academy

DEVELOPMENT OF VACUUM DROP PREDICTION FUNCTIONS IN CONVENTIONAL AND QUARTER INDIVIDUAL MILKING SYSTEMS USING RESPONSE SURFACE METHODOLOGY

S. ROSE-MEIERHOFER[1*], H. OZ[2], A. DEGIRMENCIOGLU[3], H. BILGEN[3], U. STROBEL[1] and R. BRUNSCH[1]

[1]*Leibniz Institute for Agricultural Engineering Potsdam-Bornim e.V., Department of Engineering for Livestock Management, 14469 Potsdam, Germany*
[2]*Ege University, Ege Vocational Training School*
[3] *Faculty of Agriculture, Department of Agricultural Machinery, 35100 Bornova-Izmir, Turkey*

Abstract

ROSE-MEIERHOFER, S., H. OZ, A. DEGIRMENCIOGLU, H. BILGEN, U. STROBEL and R. BRUNSCH, 2013. Development of vacuum drop prediction functions in conventional and quarter individual milking systems using response surface methodology. *Bulg. J. Agric. Sci.,* 19: 1437-1444

The objective of this study was to develop empirical functions in order to predict and compare vacuum drops in b and d-phase and in claw (or junction point) unconventional and quarter individual milking systems using response surface methodology (RSM). The independent variables considered in the study included the system-working vacuum, pulsation rate and ratio and milk flow rate. Experiments based on the central composite design (CCD), one of the designs in RSM and using water and artificial teat were conducted in the laboratory. The data obtained in the laboratory were then used to develop functions in polynomial form that allowed predicting the vacuum drops in b and d-phase and claw for both systems. The coefficient of the determination for all the models was above 93 % except the one developed for the vacuum drop prediction at junction point in quarter individual milking system. It is believed that the models developed in this study will enhance the knowledge in machine milking and could be used to design the systems for a better performance.

Key words: prediction; machine milking;central composite design; b- and d-phase; experiment design

Abbreviations: AMS - Automatic milking system; CCD - Central composite design; CON - Conventional milking system; MULTI - MultiLactor®; RMS - Response surface methodology; SCC - Somatic cell count; VC - vacuum drops in conventional milking system; VQ - Vacuum drops in quarter individual milking system

Nomenclature:

Symbol	Definition	Unit
Y	response	
β_0	intercept	
β_i, β_{ii}, β_{ij}	regression coefficients	
$X_i X_j$	coded variables	
ε	error	
ξ_i	actual values of independent variables Xi	original units (see $X_{1 \text{ to } 4}$)
$\xi^{\square}$	mean values of independent variables Xi	original units (see $X_{1 \text{ to } 4}$)
d_s	step value	
X_1	System working vacuum	kPa
X_2	Pulsation ratio	
X_3	Flow rate	L min^{-1}
X_4	Pulsation rate	pulsations per minute

E-mail: *srose@atb-potsdam.de; hulya.oz@ege.edu.tr

Introduction

Milking systems have evolved over the years with the introduction of new technology and automation and the objective of the evolutions was to obtain the whole milk from the teat of the animal in a shortest time without causing any detrimental effect on udder tissue and health while increasing the productivity by reducing the labor.

As a new system that allows milking each teat individually, MultiLactor® (MULTI) has been developed in order to eliminate the detrimental effects that induced by conventional milking systems such as teat damage and teat irritation. This system includes periodic air inlet at the teat end and can be adapted for the use in the milking parlour. It has a sequential pulsation and milking person (Rose et al., 2008) adapts cluster. As an advantage of this system using quarter individual milking in conventional milking parlours- it is expected to reduce somatic cell count as an indicator of udder health (Rose-Meierhöfer et al., 2009).

The studies using automated milking systems (AMS) mostly focused on udder health. Rasmussen et al. (2003) and Wirtz et al. (2002) found an increase in the number of bulk-milk somatic cell count once AMS was used. This shows the necessity of having an additional method to detect clinically infected cows and measuring the milk composition especially SCC per each udder quarter is important (Berglund et al., 2007; Fröhling et al., 2010).

The use of real time tests like wet and dynamic tests in order to determine the vacuum behavior in milking clusters is useful, but factorial type tests require time and effort. However, mathematical functions are helpful in order to predict the variables considered in a study for a better system design and use.

Vacuum drops occur for several reasons, including admission of air intentionally or unintentionally into the system and the sources of these drops need to be identified to maintain teat end vacuum in the desired range while operating the pump at the most energy efficient and power efficient (i.e., lowest) vacuum level. In addition to the identification of the sources, the value of vacuum drops based on the milking system and operational conditions are of importance. Ambord and Bruckmaier (2010) found more constant vacuum at the teat end during periods of high milk flow patterns, mainly at peak flow rates. Effects of higher vacuum stability on teat condition and udder health were not obvious in their investigation. The pulsation rate and ratio affect the impact of the milking cluster to teat and there are different estimations for the correct relation between them. Joe and McLean (1984) chose a ratio of 60 to 65 % and a pulsation rate of 55 to 60 for their investigations. They concluded that the proportion of clinical mastitis went down as compared to a ratio of 70:30. Besides pulsation, vacuum also has an influence on udder health. ISO 5707 (2007) suggests 32 to 42 kPa mean liner vacuum for gentle and efficient milking of cows. Optimizing these parameters in milking machines will help reducing udder health problems. In milking systems with quarter adjustable milking machine settings offers the possibility to study the effects of biological and technical factors (e.g. pulsation) on quarter milk removal parameters (Ipema and Hogewerf, 2008).

Rose–Meierhöfer et al. (2010a) found out that in quarter individual systems with periodic air inlet the reduction of the mean vacuum level in the d-phase, as the flow rate increases must provide an effective massage on the teat. The effects of this combination, lower vacuum loss in b phase and better massage effect in d-phase, could be considered as an advantage for systems with long "short milk tubes". This result corresponds well to studies conducted by Rasmussen et al. (2006). Some high fluctuations and stability problems with the vacuum were observed in the conventional milking system with long milk tubes. Studies by Öz et al. (2010a) indicated that systems with the periodic air inlet and long milk tube had stable vacuum conditions favourable to a higher milk flow. For nearly all systems the teat end vacuum decreases with increasing flow (Öz et al., 2010b; Öz et al. 2010c), but there exists no mathematical based study that enables one to predict vacuum drops under the given conditions such as system vacuum and milk flow rate.

The response surface methodology (RSM) designs are not primarily used for understanding the mechanism of the underlying system and assessing treatment main effects and interactions, but to determine, within some limits, the optimum operating conditions of a system (Myers, 1971). It is less laborious and time-consuming than other approaches and an effective technique for optimizing complex processes since it reduces the number of experimental trials to evaluate multiple parameters and their interactions (Kaur et al., 2009; Lee et al., 2006; Mangaraj and Singh, 2011).

The response surface problem usually centers on an interest in some response Y, which is a function of k independent variables $\xi_1, \xi_2, \ldots\ldots, \xi_k$, that is,

$$Y = f(\xi_1, \xi_2, \ldots\ldots, \xi_k) \quad (1)$$

and response surface can take the different forms according to the function types of response and usually response function is defined in the quadratic polynomial form as follows.

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum \beta_{ii} X_i^2 + \sum_i \sum_j \beta_{ij} X_i X_j + \varepsilon, \quad i \le j \quad (2)$$

where: $Y$is the response; $\beta_0$is the intercept; β_i, β_{ii}, β_{ij} are the regression coefficients; $X_i X_j$are the coded variables; and ε is the error.

The coding of independent variables into X_i is expressed by the following equation:

$$X_i = \frac{\xi_i - \xi^*}{d_s} \qquad (3)$$

where: ξ_i is the actual value in original units; ξ^* is the mean value (centre point); and d_s is the step value.

For a better understanding and detailed theoretical knowledge on RSM, the reader is referred to read the textbook written by Box and Draper (1987) and Yazgiand Degirmencioglu (2007) conducted one of the applications of RSM to an agricultural machinery related problem. Bade et al. (2009) applied the RSM to a milking problem. They conducted experiment based on RSM in order to quantify the milking machine effects of vacuum, b phase and liner compression on milk flow rate.

Hence a study was conducted in the laboratory and the objective of this study was to develop empirical functions in order to predict vacuum drops in b and d-phase and in claw (or junction point for quarter individual milking system) using response surface methodology (RSM) and to verify the optimum points and to compare both, conventional and quarter individual milking system.

Material and Methods

Two different types of milking systems, a conventional and a quarter individual milking unit were tested during the experiments in the milking lab designed as herringbone milking parlour located in Leibniz-Institute for Agricultural Engineering Potsdam-Bornim. The milking parlour is equipped with milk meters, with low-level vacuum line and devices that are common in many modern milking parlours. The experiments using RSM and water were conducted with artificial teats were used during the wet-tests ISO 6690 (2007). Water at room temperature was used to simulate the effects of milk flow ranged between 0-6 l/min as its physical properties are very close to milk. Vacuum measurements were made according to ISO 6690 (2007) and the data were recorded by the use of Milko Test MT52. The measuring accuracy and scan frequency of this device are < 0.5 % and 1 kHz, respectively and it is specially designed for testing vacuum pumps, milking equipments and pulsators. The vacuum was recorded for 21 pulse cycles for each measurement at the ISO-teat end, pulse chamber, claw and main vacuum line, simultaneously. From the data recorded, the meanvacuum in b-phase, the mean vacuum in d-phase, and the percent share of the phases of the pulsation cycle were calculated at each one of twelve randomly selected pulsation cycles.

The conventional milking cluster manufactured by GEA (Bönen, Germany) with a claw volume of300 cc (CON) was used as a reference cluster. As a second system, MultiLactor® (Siliconform GmbH Türkheim, Germany) (MULTI) is a quarterindividual milking system that can be used in conventional milking parlour. The length of the long milk tubes and the inside diameter are 2100 and 10 mm, respectively. The pulse tubes have thesame length with long milk tubes but they have an inside diameter of 8 mm. The teat cups with silicon liners have Bio-Milker-System®that allows periodic air inlet to the pulse chamber. This system has a different concept in terms of pulsation type called sequential pulsation. This means that pulsation starts in each liner individually and shifts 0.25 % of the total pulsation duration. This system provides a better distribution when milk comes together in the long milk tube and the fluctuations are lower, compared to simultaneous pulsation (Rose-Meierhöfer et al., 2010b).

The vacuum drops in b- and d-phase and in claw (or junction point for quarter individual milking system) were found as a function of four independent variables considered in this study. The vacuum drops in conventional (VC) and quarter individual milking system (VQ) were determined as the difference between the system vacuum and teat end vacuum at randomly selected sequential 12 cycles.

The independent variables were system working vacuum, pulsation rate and ratio and flow rate. The coded and uncoded levels of the variables are given in Table 1.

A total of 30 experiments was carried out in the laboratory based on CCD and five levels of each independent variable were considered. The results from the experiments were used to develop functions for each dependent variable. A general theoretical cubic function for four variables in full

Table 1
Coded and uncoded level of independent variables used in the development of RSM functions

Independent variables		Coded level				
		-2	-1	0	+1	+2
System working vacuum, kPa	X_1	30	37	44	51	58
Pulsation ratio	X_2	50:50	57:43	62:38	66:34	70:30
Flow rate, L min^{-1}	X_3	2	3.5	5	6.5	8
Pulsation rate	X_4	41	53	65	77	89

was defined and submitted to a statistical package program and stepwise regression procedure was applied in order to select the variables at a probability level of 95%.

Results and Discussion

The experimental results obtained in the laboratory based on CCD are tabulated in Table 2 for conventional and quarter individual milking systems.

As seen from the table above, vacuum drops in b-phase are similar for both conventional and quarter individual milking while the differences between the d-phase are significant. These differences could be attributed to constructional differences between the two systems, mainly periodic air inlet to the pulse chamber in quarter individual milking system. The comparison of these two systems based on the raw data given above is depicted in Figures 1 and 2 for b and d-phase, respectively.

As seen from the figures, the behaviour of the systems in b-and d-phase is similar even though the vacuum drop values in d-phase are comparable different.

From the data presented in Table 2, the following polynomial functions were developed for the vacuum drops in b and

Table 2
CCD design with coded independent variables and measured vacuum drops in b and d-phase and in claw (or junction point) for conventional and quarter individual milking systems

Design point	Coded and uncoded independent variables				Vacuum drops (kPa) for conventional milking system			Vacuum drops (kPa) for quarter individual milking system		
	X_1	X_2	X_3	X_4	VC_b	VC_d	VC_w	VQ_b	VQ_d	VQ_w
1	+1(51)	-1 (57:43)	+1 (6.5)	+1 (77)	7.86	10.02	8.35	6.85	29.26	3.90
2	+1(51)	-1(57:43)	-1(3.5)	+1(77)	3.39	4.96	4.91	3.99	20.10	2.09
3	-1(37)	+1 (66:34)	-1(3.5)	+1 (77)	3.86	5.48	4.34	2.79	19.33	0.72
4	+2 (58)	0 (62:38)	0 (5)	0 (6.5)	6.80	7.81	6.64	7.51	27.73	3.95
5	+1(51)	-1 (57:43)	-1(3.5)	-1(53)	4.27	4.87	4.93	3.12	20.94	1.58
6	+1 (51)	+1 (66:34)	-1(3.5)	-1(53)	4.61	6.81	5.14	3.85	22.29	1.54
7	0 (44)	0 (62:38)	-2 (2)	0 (65)	2.52	2.91	2.87	1.57	12.35	0.35
8	-1(37)	-1 (57:43)	-1(3.5)	-1(53)	4.21	4.74	3.83	2.84	16.60	0.74
9	+1 (51)	+1 (66:34)	+1(6.5)	-1(53)	9.14	9.70	8.49	7.97	29.29	3.03
10	0 (44)	+2 (70:30)	0 (5)	0 (65)	6.40	8.23	5.96	5.60	26.35	1.68
11	+1 (51)	+1 (66:34)	-1(3.5)	+1(77)	4.11	5.30	4.83	4.36	22.18	1.37
12	-2 (30)	0 (62:38)	0 (5)	0 (65)	5.63	7.88	4.96	4.06	19.30	3.35
13	-1 (37)	+1 (66:34)	+1(6.5)	-1(53)	7.05	8.31	6.38	5.34	23.81	3.97
14	-1 (37)	-1 (57:43)	+1(6.5)	-1(53)	7.02	7.41	6.62	6.41	21.26	4.26
15	+1 (51)	-1 (57:43)	-1(3.5)	+1(77)	3.59	4.56	4.82	4.05	19.86	2.08
16	+1 (51)	+1 (66:34)	+1(6.5)	+1(77)	8.85	10.74	8.58	7.96	33.62	3.27
17	-1 (37)	-1 (57:43)	-1(3.5)	+1(77)	3.66	3.91	3.94	3.10	16.47	3.45
18	-1 (37)	+1 (66:34)	+1(6.5)	+1(77)	7.08	8.95	5.92	4.92	26.06	4.40
19	0 (44)	0 (62:38)	0 (5)	-2 (41)	6.06	6.56	6.17	4.33	24.28	1.21
20	0 (44)	0 (62:38)	0 (5)	+2 (80)	5.25	7.31	5.68	3.54	25.05	2.20
21	-1 (37)	-1 (57:43)	+1(6.5)	+1(77)	6.87	8.63	6.15	5.60	24.78	4.38
22	0 (44)	-2 (50:50)	0 (5)	0 (65)	5.34	6.80	6.11	4.54	20.37	1.61
23	-1 (37)	+1 (66:34)	-1(3.5)	-1(53)	4.05	5.89	3.84	3.16	17.58	3.12
24	0 (44)	0 (62:38)	+2 (8)	0 (65)	10.30	12.48	9.55	7.08	29.81	3.03
25	0 (44)	0 (62:38)	0 (5)	0 (65)	6.22	8.01	6.03	4.48	22.52	1.85
26	0 (44)	0 (62:38)	0 (5)	0 (65)	6.10	7.61	5.91	4.68	22.27	1.77
27	0 (44)	0 (62:38)	0 (5)	0 (65)	6.13	7.71	5.82	4.45	22.54	1.80
28	0 (44)	0 (62:38)	0 (5)	0 (65)	6.09	8.07	6.21	4.41	22.22	1.55
29	0 (44)	0 (62:38)	0 (5)	0 (65)	6.17	7.66	6.07	4.56	22.38	1.65
30	0 (44)	0 (62:38)	0 (5)	0 (65)	6.07	7.72	6.06	4.79	22.52	1.63

d-phase and in claw for both, conventional and quarter individual milking systems. The models given below are written in the order that the variables entered into the model so that the significance of each term to the model could be identified from this order.

The models developed for conventional milking system are as in the following.

The vacuum drop model in b-phase:

$VC_b=6.185+1.908X_3+0.359X_1+0.417X_1X_3-0.209X_4+0.211X_2-0.144X_4^2-0.09X_2^2$ (R^2=98.9 %)

The vacuum drop model in d-phase:

$VC_d= 7.573+1.834X_3+0.48X_1X_2^2+0.418X_2+0.382X_3X_4-0.244X_4^2+0.327X_1X_3+0.139X_3^3$ (R^2=97.5 %)

The vacuum drop model in claw:

$VC_W= 5.943+1.556X_3+0.846X_1+0.383X_1X_3-0.107X_1^3$ (R^2=96.6 %)

The vacuum drop models for the conventional milking system were formed by all of the variables considered in this study except the claw model. This model was only formed by system working vacuum and the flow rate.

The models developed for quarter individual milking system are given below.

The vacuum drop model in b-phase:

$VQ_b= 4.385+1.577X_3+0.787X_1+0.348X_1^2+0.261X_1X_3-0.313X_3X_4+0.28X_1X_2+0.17X_2^2$ (R^2=95.9 %)

The vacuum drop model in d-phase:

$VQ_d= 22.52+4.19X_3+2.29X_1+0.43X_2^3+0.82X_1^2X_4+0.78X_1X_3+0.52X_4^2$ (R^2=93.6 %)

The vacuum drop model at junction point:

$VQ_j= 1.974+0.90X_3+0.56X_1^2+0.35X_2X_3X_4-0.34X_2X_4$ (R^2=77.1 %)

The models written above for conventional and quarter individual milking system in general predict vacuum drops with an acceptable coefficient of determination while the predictions for the vacuum drop at junction point for quarter individual milking is low. This means that the predictions for this model could be misleading.

The models are valid under the following conditions (in uncoded levels):

$58\ kPa \geq V \geq 30\ kPa$
$70{:}30 \geq P_r \geq 50{:}50$
$8\ L\ min^{-1} \geq Q \geq 2\ L\ min^{-1}$
$89 \geq P_t \geq 41$,

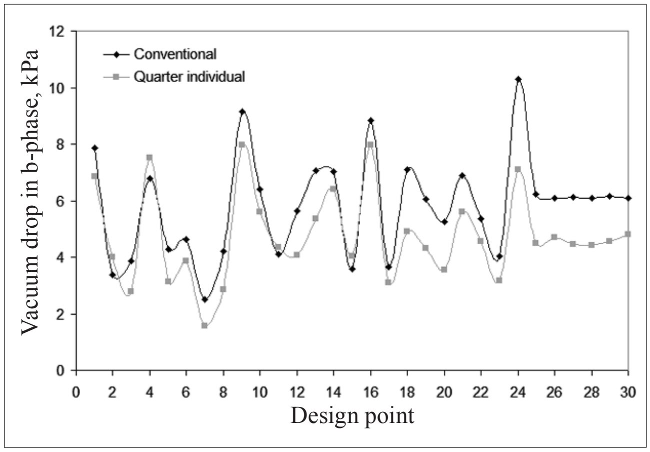

Fig. 1. Vacuum drops in b-phase in conventional and quarter individual milking system based on the experiments conducted

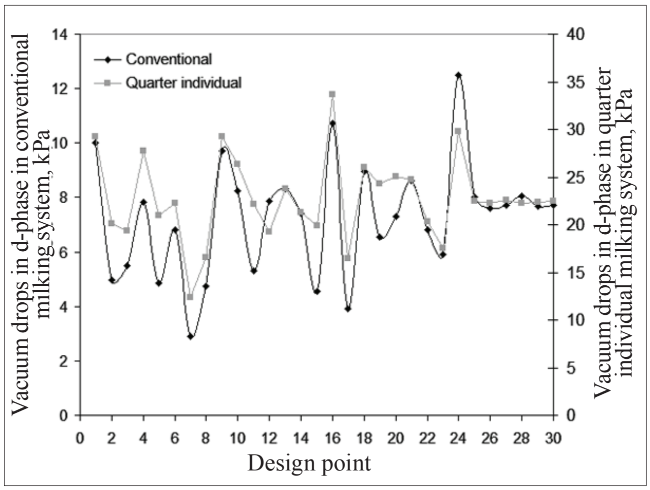

Fig. 2. Vacuum drops in d-phase in conventional and quarter individual milking system based on the experiments conducted

where V is the system working vacuum, P_r is the pulsation ratio, Q is the flow rate and P_t is the pulsation rate.

Many graphs can be generated using the above written models in order to understand the differences between the two systems but some of the typical response surfaces are depicted in Figure 3 and 4 for conventional and quarter individual milking systems.

As seen from the contour graphs given above (Figures 3a, b and 4a, b), the differences in construction in the milking systems affect the vacuum drops in b and d-phase. The significance difference is noticeable especially in d-phase.

Rasmussen and Madsen (2000) described in details that milking at low vacuum (as they specified to be 26 to 30 kPa and calculated as the average of a-, b-, c- and d-phase) in contrast to high vacuum (as they mentioned to be 33 to 39 kPa) extends the averaged milking time and increases the frequency of climbing liners. For a high vacuum, in contrast, it could be shown that the average milking time only moderately shortened (Reinemann et al., 2001), but the amount of open teat ends after milking increased. Further, high vacuum also increased the time needed by the teat ends to close again. Additionally, high vacuum increases the amount of hyperkeratosis at the teat end, as in previously mentioned studies (Mein, Williams, Reinemann, 2003).

Some verification tests were carried out at a vacuum level of 39 kPa that was found to be optimum system vacuum level to minimize the vacuum fluctuations (Öz et al., 2011) and the test results are given in Table 3 and 4 for b-phase for both conventional and quarter individual milking systems. As seen from the tables, the predicted vacuum drops are in good agreement with the measured values. On the other hand, the verification test results are given in Table 5 for claw in conventional system as well. No comparison was made for the vacuum drops at junction point for the quarter individual milking system since the coefficient of determination for the prediction model was considerable low.

Conclusions

The following conclusions were drawn from the study conducted:

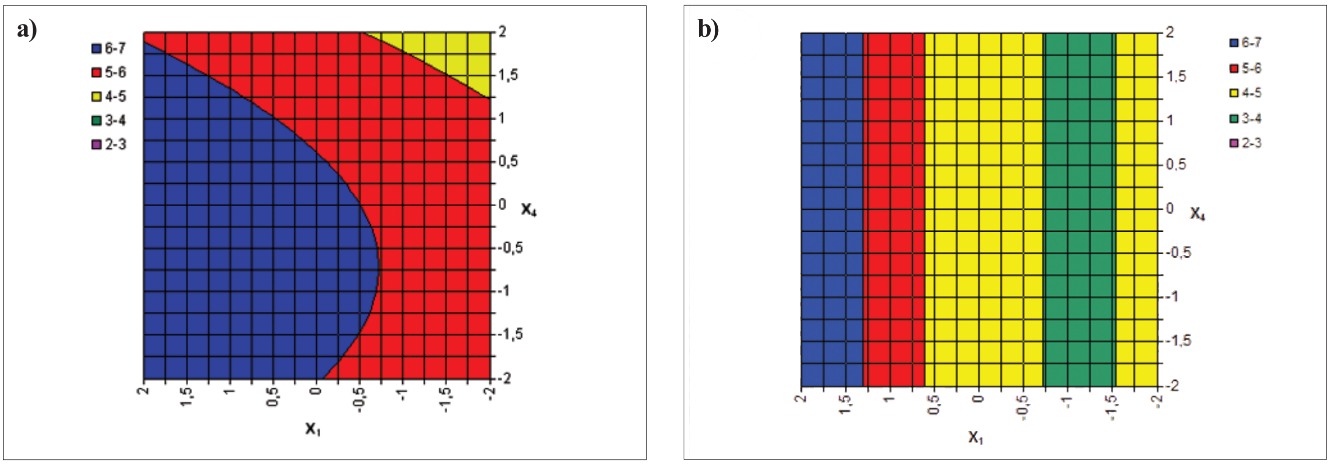

Fig. 3. Vacuum drops in b-phase in kPa a) conventional b) quarter individual milking system as a function of system working pressure (X_1) and pulsation rate (X_4) (pulsation ratio, X_2 andflow rate X_3 are kept constant at the center, zero level)

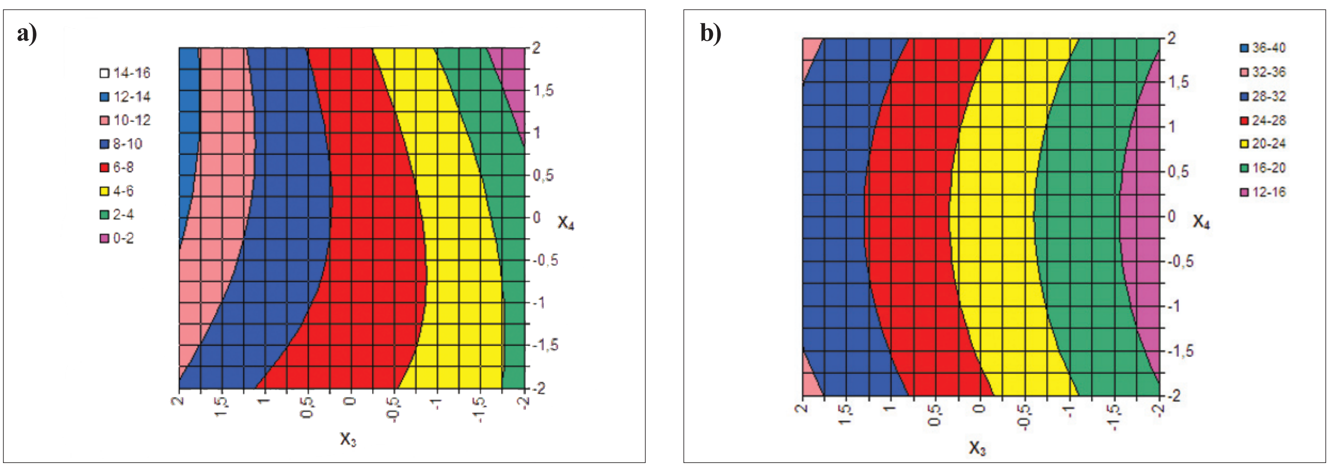

Fig. 4. Vacuum drops in d-phase in kPa a) conventional b) quarter individual milking system as a function of flow rate (X_3) and pulsation rate (X_4) (system working pressure, X_1 and pulsation ratio, X_2 are kept constant at the center, zero level

- Vacuum drops in b and d-phase in conventional and quarter individual milking systems and in claw in conventional milking system were affected by the variables considered in this study, namely system working vacuum, flow rate, pulsation rate and ratio.
- The values of vacuum drops in b-phase were similar while the differences in d-phase were significant when the conventional and quarter individual systems are compared and this could be attributed to the constructional differences in the milking systems considered in this study.
- It is believed that the models developed in this study could be used with an acceptable level of accuracy for the prediction of vacuum drops in conventional and quarter individual milking systems.

References

Ambord, S. and R. M. Bruckmaier, 2010. Milk flow-dependent vacuum loss in high-line milking systems: Effect on milking characteristics and teat tissue condition. *Journal of Dairy science*, **93** (8):3588-3594.

Bade, R. D., D. J. Reinemann, M. Zucali, P. L. Ruegg and P. D. Thomson, 2009. Interactions of vacuum, b-phase duration and liner compression on milk flow rates in dairy cows. *Journal of Dairy Science,* **92:** 913-921.

Berglund, I., G. Petterson, K. Ostenson and K. Svennersten-Sjauna, 2007. Quarter milking for improved detection of increased SCC. *Reproduction in Domestic Animals,* **42:** 427-432.

Box, G. E. P. and N. Draper, 1987. Empirical Model-Building and Response Surfaces. *John Wiley and Sons*, New York, USA.

Table 3
Measured and predicted vacuum drops in b-phase for conventional milking system

Coded and uncoded independent variables				Vacuum drop	
X_1	X_2	X_3	X_4	Measured	Predicted
-0,71 (39)	-1 (57:43)	-1 (3.5)	+0,833 (75)	3.83	3.73
-0,71 (39)	-1(57:43)	0 (5)	+0,833 (75)	6.16	5.35
-0,71 (39)	-1(57:43)	-1 (3.5)	-0,42 (60)	4.04	4.07
-0,71 (39)	-0,41 (60:40)	0 (5)	-1 (53)	4.58	5.89
-0,71 (39)	-0,41 (60:40)	0 (5)	-0,42 (60)	6.11	5.89
-0,71 (39)	-1(57:43)	-1 (3.5)	+1 (77)	3.94	3.66
-0,71 (39)	-1(57:43)	0 (5)	+1 (77)	6.21	5.27

Table 4
Measured and predicted drops in b-phase for quarter individual milking system

Coded and uncoded independent variables				Vacuum drop	
X_1	X_2	X_3	X_4	Measured	Predicted
-0,71 (39)	-1 (57:43)	-1 (3.5)	+0,833 (75)	1.16	3.29
-0,71 (39)	-1(57:43)	0 (5)	+0,833 (75)	2.53	4.37
-0,71 (39)	-1(57:43)	-1 (3.5)	-0,42 (60)	2.55	2.84
-0,71 (39)	-0,41 (60:40)	-1 (3.5)	-1 (53)	2.87	2.40
-0,71 (39)	-0,41 (60:40)	0 (5)	-0,42 (60)	4.08	4.11

Table 5
Measured and predicted vacuum drops in claw for conventional milking system

Coded and uncoded independent variables				Vacuum drop	
X_1	X_2	X_3	X_4	Measured	Predicted
-0,71 (39)	-1 (57:43)	-1 (3.5)	+0,833 (75)	7.18	4.09
-0,71 (39)	-1(57:43)	0 (5)	+0,833 (75)	5.26	5.38
-0,71 (39)	-1(57:43)	-1 (3.5)	-0,42 (60)	3.36	4.09
-0,71 (39)	-0,41 (60:40)	0 (5)	-1 (53)	3.90	5.38
-0,71 (39)	-0,41 (60:40)	0 (5)	-0,42 (60)	5.56	5.38
-0,71 (39)	-1(57:43)	-1 (3.5)	+1 (77)	3.80	4.09
-0,71 (39)	-1(57:43)	0 (5)	+1 (77)	5.03	5.38

Fröhling, A., M. Wienke, S. Rose-Meierhöfer and O. Schlüter, 2010. Improved Method for Mastitis Detection and Evaluation of Disinfectant Efficiency during Milking Process. *Food and Bioprocess Technology,* **3:** 892-900.

Ipema, A. H. and P. H. Hogewerf, 2008. Quarter-controlled milking in dairy cows. *Computer and Electronics in Agricultural Sciences,* **62:** 59-66.

ISO/DIN 5707, 2007. Milking machine installations - constructions and performance. International Organization for Standardization.

ISO/DIN 6690, 2007. Milking machine installations - mechanical tests. International Organization for Standardization.

Joe, A. and D. MacLean, 1984. Milking Machines and Mastitis. In: Dairy Cattle Society of the New Zealand Veterinary Association., Proceedings of the Society's seminar, Massey University, 30 November-1 December, 1984. 1984, 116-117. Palmerston North, New Zealand.

Kaur, S., B. C. Sarkar and H. K. Sharma, 2009. Optimization of Enzymatic Hydrolysis Pretreatment Conditions for Enhanced Juice Recovery from Guava Fruit Using Response Surface Methodology. *Food Bioprocess Technology*, **2:** 96-100.

Lee, W. C., S. Yusof, N. S. A. Hamid and B. S. Baharin, 2006. Optimizing conditions for enzymatic clarification of banana juice using response surface methodology (RSM). *Journal of Food Engineering*, **73:** 55-63.

Mangaraj, S. and K. P. Singh, 2011. Optimization of Machine Parameters for Milling of Pigeon Pea Using RSM. *Food and Bioprocess Technology*, **4:** 762-769.

Mein, G. A., D. M. Williams and D. J. Reinemann, 2003. Effects of milking on teat-end hyperkeratosis: 1. mechanical forces applied by the teatcup liner and responses of the teat. *Proceedings, 42nd Annual Meeting of the National Mastitis Council,* 26.-29 .01.2003, Fort Worth, USA.

Myers, R., 1971. Response Surface Methodology. Allyn& Bacon Inc., Boston, Mass., USA.

Öz, H.,S. Rose-Meierhöfer, H. Bilgen and R. Brunsch, 2010a. Determination of vacuum characteristics in conventional and single tube milking systems using wet test method. *Milk Science International*, **65** (3): 238-241.

Öz, H., S. Rose-Meierhöfer and A. Degirmencioglu, 2010b. Prediction and Comparison of Vacuum Related Variables in Conventional and Quarter Individual Milking Systems. *Journal of Agricultural Machinery Science,* **6** (3): 197-202.

Öz, H., S. Rose-Meierhöfer, U. Ströbel and C. Ammon, 2010c. Comparison of the Vacuum Dynamics of Conventional and Quarter Individual Milking Systems. *Journal of Agricultural Machinery Science,* **16** (3): 162-168.

Öz, H., S. Rose-Meierhöfer, A. Degirmencioglu, U. Ströbel, R. Brunsch, H. Bilgen and U. Erdogan, 2011. Mathematical Modeling and optimization of vacuum related variables in conventional and quarter individual milking systems using response surface methodology. *Milk Science International*, **66** (2):119-123.

Rasmussen, M. D. and N. P. Madsen, 2000. Effects of Milkline Vacuum, Pulsator Airline

Vacuum, and Cluster Weight on Milk Yield, Teat Condition, and Udder Health. *Journal of Dairy Science*, **83** (1): 77-84.

Rasmussen, M. D., D. J. Reinemann and G. A. Mein, 2003. Measuring Vacuum in Milking Machines. *The Bulletin of International Dairy Federation* 381, Belgium.

Rasmussen, M. D., L. Wiking, M. Bjerring and H. C. Larsen, 2006. Influence of Air intake on the concentration of free fatty acids and vacuum fluctuations during automatic milking. *Journal of Dairy Science*, **89:** 4596-4605.

Reinemann, D. J., M. A. Davis, D. Costa and A. C. Rodriguez, 2001. Effects of Milking Vacuum on Milking Performance and Teat Condition. *Proceedings, AABP- National Mastitis Council.* International Symposium on Mastitis and Milk Quality, 13-15.09.2001, Vancouver, Canada.

Rose, S., H. Öz, R. Brunsch and H. Bilgen, 2008. Wet and Dynamic Tests in Conventional and Single Tube Milking Clusters. *Journal of Agricultural Machinery Science*, **4** (4): 343-348.

Rose-Meierhöfer, S., R. Brunsch and M. Jakob, 2009. Reduction of forces on the teats by single tube guiding in conventional milking parlours. *South African Journal of Animal Science,* **39** (1):161-164.

Rose-Meierhöfer, S., H. Öz, U. Ströbel, A. Fröhling and R. Brunsch, 2010a. Individual quarter milking in a conventional milking parlour. In: Hillerton, E. (ed.): Mastitis research into practice. 5th IDF Mastitis Conference, Christchurch, 21.03.-24 .03.2010, VetLearn, Wellington, 2010, pp. 454-458.

Rose-Meierhöfer, S., G. Hoffmann, H. Öz, U. Ströbel and C. Ammon, 2010b. Milking-time tests in conventional and quarter-individual milking systems. *LandbauforschungVölkenrode - vTI Agriculture and Forestry Research*, **60** (1): 11-15.

Wirtz, N., K. Oechtering, E. Tholen, W. Trappmann, J. McLean and M. Sinclair, 2002. Comparison of an automatic milking system to a conventional milking parlor. In: *Proceedings of First North American Conference on Robotic Milking, III-50-III-53, Toronto, Canada.*

Yazgi, A. and A. Degirmencioglu, 2007. Optimisation of the seed spacing uniformity performance of a vacuum type precision seeder using response surface methodology. *Biosystems Engineering*, **97** (3): 347-356.

Received February, 5, 2013; accepted for printing September, 2, 2013.