Mathematical Modeling of Vacuum Related Variables in Conventional Milking Systems Using Response Surface Methodology

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Introduction

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

The objective of this study was to develop mathematical functions for vacuum related variables namely mean vacuum, mean claw vacuum, average b and d-phase vacuum in conventional milking systems using Response Surface Methodology (RSM).

In order to develop functions in a conventional milking system, four independent variables namely vacuum, pulsation rate and ratio and flow were considered in the study. Experiments using five levels of each variable and Central Composite Design (CCD), one of the RSM Designs were conducted in Achselschwang Research and Education Farm in Bavaria- Germany. The 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 (Lee et, al., 2006). Prediction functions in cubic form for b and d-phase and mean system vacuum and mean claw vacuum were developed.

Materials and Method

Artificial teats were used during the wet tests and vacuum measurements were made according to ISO 6690 (2007) and the data recorded by the use of Milkotest MT52. The vacuum related dependent variables such as mean vacuum and mean claw vacuum, average vacuum at d- and b-phase and fluctuations were found as a function independent variables considered in this study. These independent variables were system working vacuum, pulsation rate and ratio and flow rate. A total of thirty experiments were carried out in the laboratory and five levels of each independent variable were used. The results from the experiments were used to develop functions for each dependent variable.. A general theoretical cubic function for four variables in full was defined and submitted to a statistical package program and stepwise regression procedure was applied in order to select the variables at a level of 95%.

Results

The response surface functions are developed to find out the optimum level of the variables. In such case, the optimum levels are only valid for the fluctuations not for the mean vacuum or B and D-phase since only fluctuation related variables can be optimized and this is considered to be a minimization problem. The relationship between the optimized fluctuation variables can then be related to the mean vacuum, mean claw vacuum, d and b-phase values. For this reason, prediction functions for each independent variable has to be developed as it is the case in this study.

The function developed obtained in this study for mean vacuum (Y_m) as an example is given below.

$$Y_m = 37.79 + 6.6 X_1 - 1.17 X_3 - 0.76 X_1X_2 + 0.84 X_2X_4 - 0.97 X_3X_4 - 1.16 X_1^2X_2 + 0.74 X_1^2X_4$$

Where the coded form of the variables were X_1, the system working vacuum; X_2, pulsation ratio; X_3, flow rate and X_4, pulsation rate. The coefficient of determination of the above written function is 91.06 % and it allows predicting the mean vacuum as a function of above written variables.

Other functions for mean claw, average b and d phase were also developed with an acceptable level of coefficient of determination and they were all in a reduced form of a cubic polynomial function.

The significance of the models in terms of uncoded variables and requirements as indicated in ISO standards will be discussed and evaluated.

References

Bade, R.D., D.J. Reinemann, M. Zucali, P.L Ruegg and P.D. Thompson. 2009. Interaction of vacuum, b-phase duration, and liner compression on milk flow rates in dairy cows. J. Dairy Sci. 92:913.

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

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

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

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