Stefan D. Köhler and Otto Kaufmann, Berlin

Statistical model for the identification of udder disease in AMS

The reliability of early identification of udder diseases in AMS is not good enough. More criteria for increasing mastitis diagnosis reliability must be established. From a 105-cow herd milked through two AMS the parameters milk production rate, milk flow and intermilking periods were analysed individually and in combination with the milk electrical conductivity. Whilst one-parameter models indicated higher specificity values, the best continuous sensitivity performance was through linking the four initial parameters through index models.

Stefan D. Köhler is a member of the scientific staff at the Institute for Agricultural and Urban Ecological Projects (IASP) at the Humboldt University, Berlin, Invalidenstr. 42, 10115 Berlin; e-mail: *stefan.d.koehler@agrar.hu-berlin.de*
Prof. Dr. Otto Kaufmann lectures at the Institute for Natural Sciences at the Humboldt University, Philippstr. 13, 10115 Berlin.
The work was financially supported by the Vereins für Agrar- und Stadtökologische Projekte e.V.

Keywords

Udder health, AMS, milking parameters, milk parameters, statistical models

Literature

Literature information is available under LT 02606 in Internet at http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm

Because visual control by the milker no longer takes place with automatic milking systems (AMS), udder health and milk quality require special attention to meet the legal milk hygiene requirements. Currently, however, diagnosis of clinical and sub-clinical mastitis on AMS farms [1, 2] is hardly ever conducted. The aim here, therefore, was to model in a simple way assumed relationships between milking and milk parameters on the one hand and udder health on the other.

Material and methods

On the investigated farm around 105 Holstein cows producing an average 6500 to 7000 kg per lactation were milked by two AMS (Lely Astronauts). Udder quarter health was evaluated using DVG (1994) recommendations. Udder quarters were described as „conspicuous“, i.e. more or less diseased, where a cell count of > 100 000 and a positive bacteriological result was registered. „Inconspicuous“, on the other hand, meant a cell count of < 100 000 and no positive result. Classified as a „positive“ were clinical secretion changes or evidence of mastitis microorganisms. Significant clinical udder changes are noted (atrophic, hardened-enlarged, lumpy quarters).

On five consecutive days (March 2002) the milk from individual quarters was continuously sampled on both AMS by eight „LactoCorder low flow“ machines (WMB AG). Milk flow was measured in average main flow minutes (DMHG). The standard non-indicated value ELHMF (electrical conductivity during peak milk flow) was recorded and processed after preliminary manipulation of data „Lacto.ini“. Intermilking period was arrived at by subtracting the time entries of consecutive data inputs. The milk production rate was calculated as quotient of the recorded values MGG (total milk via AMS) and the associated intermilking periods.

Used for identification of disease-signifying changes was the standardisation of current recordings with the help of quarter-specific normal values. The system used with AMS standardises previous recordings (running average) using the arithmetical n, an approach that does not so far take account of the very different individual quarter physiological variation range of „normal“ values. If one assumes a normal distribution of healthy udder quarter characteristics, a statistical mass can then be created for this variation range of the standard deviation. The normal value of a parameter would then be the running average plus a certain proportion (e.g. the half) of the standard deviation:

- Milk production rate:
  $(w_{norm} = (w / (average - 0,5 \cdot s)$
- Milk flow
  $x_{norm} = (x / (average - 0,5 \cdot s)$
- Intermilking period
  $y_{norm} = (y / (average + 0,5 \cdot s)$
- Leitfähigkeit:
  $z_{norm} = (z / (average + 0,5 \cdot s)$

whereby w_{norm}, x_{norm}, y_{norm} and z_{norm} symbolise the standardised parameter values, w, x, y and z the absolute values, s the standard deviation of the spot test and 0.5 the factor for the confidence interval.

For modelling the assumed relationships between milk production rate, milk flow, intermilking period and electrical conductivity on the one hand and the udder health on the other, simple statistical concepts (single-parameter models, index models) were applied.

Table 1: Comparison of standardised parameter values (U= inconspicuous, A = conspicuous)

	MBR		MF		ZMZ		LF	
	U	A	U	A	U	A	U	A
Average	1.02	0.83	1.04	0.91	0.93	1.00	0.99	1.06
s	0.21	0.23	0.16	0.20	0.22	0.18	0.04	0.09
Min	0.31	0.41	0.60	0.51	0.51	0.61	0.86	0.90
Max	1.76	1.80	1.79	1.68	1.91	1.47	1.13	1.34
t-value	5.491		4.858		1.975		9.237	

The average value differences are statistically at least significant ($p<0.05$). Critical t-values; $\alpha = 0.1:1.653$; $\alpha = 0.01:2.601$; $\alpha = 0.001:3.340$.

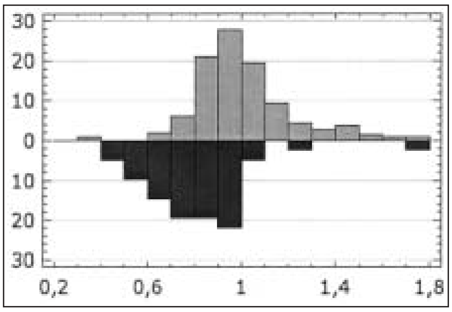

Fig. 1: Comparison of the relative frequency distribution (left in %) for the standardized milk production rate of „inconspicuous" (above) and „conspicuous" (below) udder quarters.

Threshold value models belong to the first group. The models GW1 to GW4 recognised a deviation of 5% from normal value as „conspicuous". In the models GW5 to 8 „conspicuous" was only diagnosed where there was a 10% worsening of the respective parameters. All initial parameters could be linked together in the second group of models. Thus deviations from normal value (1.00) with regard to their respective importance were added up through the following equation:

$$i = (w_{norm} - 1) + (x_{norm} - 1) + (1 - y_{norm}) + (1 - z_{norm})$$

The indices i with negative preceding symbol thus indicate „conspicuous" whereby values at or above or absolute zero mean „inconspicuous". Model index 1 links all deviations without a special weighting for one of the four parameters. In the models index 2 to 5 the milk production rate (2), milk flow (3), intermilking period (4) or conductivity (5) were successively weighted higher by the factor 2 before the respective term.

Depending on an analysis of the crude data, especially the conspicuous lines, the standard values of milk production rate, milk flow, and intermilking period were ordered with the standardised conductivity value of the previous recording. This approach was additionally secured through results from the literature according to which the conductivity could be shown by (where possible) registerable piks shortly before identifiable changes in the milk [3, 4]. The data concept modelled for the m-te milking of a quarter contained therefore the data fields:

$[w_{norm}(m)]$; $[x_{norm}(m)]$; $[y_{norm}(m)]$; $[z_{norm}(m-1)]$

with the given importance of the variables w_{norm}, x_{norm}, y_{norm} und z_{norm}.

For comparison, an alarm list from the memory files of the robot software from both milking robots was prepared. This contained all AMS information regarding increased conductivity values and abnormal milk quality (MQC) within the trial period plus the previous day. The mass amount „probability of diagnosis error" applied as quotient from the number of wrong classifications and the total of data sets (474). All calculations were carried out with programs Excel 2000, Access 2000 and Statgraphics Plus 5.0.

Results

The different models were tested on parameter values standardised through 474 data sets which had been calculated from 2826 individual data sets from 195 „inconspicuous" and 41 „conspicuous" udder quarters. *Table 1* shows the data from the standardised parameters. How the frequency distribution of certain characteristic „inconspicuous" and „conspicuous" quarters differ from one another after class formation can be seen very well from the standardised milk production rate and the standardised electrical conductivity (*figs. 1 and 2*). *Table 2* shows the results for the one-parameter models (threshold value models) the evaluation of milking robot signals and the balance of the index models.

Discussion

With all input parameters the standardisation gave the expected differences for the average values of the groups „inconspicuous" and „conspicuous". Standardised milk production rate and standardised milk flow of „conspicuous" quarters lay substantially under those of the „conspicuous" ones, whereas standardised intermilking periods and conductivity were increased.

Comparing the models made it clear that the index models were more sensitive. Alone the combination of several criteria can, i.e., already deliver the wished for addition in recognition of conspicuously altered lines. In comparison, one-parameter models showed a tendentially high specificity. This applied mainly for the parameter standardised electrical conductivity (98.2 and 99.8%). This exception was caused by a permitted deviation of 10% from normal value and a very low calculated quota of wrong diagnoses (6.8%). Positive in comparison to the otherwise low sensitivity values is the parameter milk production rate within the threshold value models. With an acceptance of 5% deviation from normal value 30 from 41 conspicuous udder quarters could still be identified.

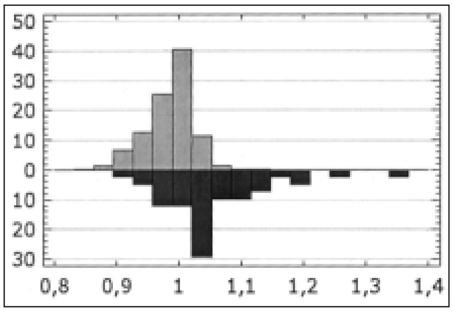

Fig. 2: Comparison of the relative frequency distribution (left in %) for the standardized electric conductivity of „inconspicuous" (above) and „conspicuous" (below) udder quarters

Through optimisation according to two lines (high sensitivity plus low probability of false classifications) it was possible in the above case to give preference to threshold value model 4. For the combined alarm list of the AMS only a very slightly increased possibility of false diagnosis was calculated. This was paired however with a hardly acceptable sensitivity of 17.1%.

The results from the one-parameter and index models allow the following three conclusions:

- changes in the milk production rate are especially suitable for in helping to identify the presence of udder disease
- main role for specific electric conductivity is the identification of healthy udder quarters
- linking several parameters means a clear rise in sensitivity can be expected.

Literature

Books are identified by •

[1] *Hamann, J.*: Vollautomatisierte Milchgewinnung und tierärztliche Herdenbetreuung. Tierärztliche Umschau 54 (1999), H. 6, S. 306-310

[2] *Pallas, S. and K. Wendt*: The development of udder health of a dairy cow herd in automatic milking system. Hrg.: Rosati, A., S. Mihina and C. Mosconi: Physiological and technical aspects of machine milking. International Conference, Proc., Nitra, 26.-27. 6. 2001, pp. 175-179

[3] *Milner, P., K. L. Page, A. W. Walton and J. E. Hillerton*: Detection of mastitis by changes in electrical conductivity of foremilk before visible changes in milk. Journal of Dairy Science 79 (1996), no.1, pp. 83-86

[4] • *Umstätter, C.*: Tier-Technik-Beziehung bei der automatischen Milchgewinnung. Dissertation, Humboldt-Universität zu Berlin, 2002

Table 2: Results of modeling by means of threshold values or formation of indices and comparison with AMS-model

Parameter	Milchbildung		Milchfluss		Zwischenmelkzeit		Leitfähigkeit		AMS	Verknüpfung aller vier Parameter				
Modell	GW 1	GW 5	GW 2	GW 6	GW 3	GW 7	GW 4	GW 8		Index 1	Index 2	Index 3	Index 4	Index 5
Sensitivität (%)	73,2	63,4	65,9	46,3	58,5	19,5	41,5	24,4	17,1	90,2	**92,7**	87,8	75,6	90,2
Spezifität (%)	60,3	72,1	70,7	83,4	77,6	85,5	98,2	**99,8**	99,5	65,4	57,7	64,9	69,7	66,5
Fehldiagnosen (%)	38,6	28,7	29,7	19,8	24,1	20,3	**6,8**	**6,8**	7,6	32,5	39,2	33,1	29,7	31,4